



The Blast Furnace and Steel Plant

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The Blast Furnace *and* Steel Plant

VOL. IX.

PITTSBURGH, PA., SEPTEMBER, 1921

No. 9

Discussion on Open Hearth Practice

Segregation In Basic Open Hearth Steel—The Effect of the Acid Slag in Causing Segregation Is Shown by a Series of Tables.

By HENRY WILLIAM SELDON, B.S., Met.Eng.,
Sec-Seldon and Associates, Engineers.

THE claim department of the steel mill is not interested in the good steel the mill is making, but, rather, in the bad. If one were to form his impression entirely from the information available in the claim department he would be inclined to question if the company made any good steel at all. When the steel is satisfactory to the customer nothing is said, but let the customer have trouble with the steel and a complaint is lodged at once. It is also surprising how the condition of the times influence the customers' claims. When times are booming and steel is hard to get the customer is apparently not so particular and the claims are proportionately low. However, as times get harder and more steel is available, the proportion of claims at once increase.

In some cases the customer himself is at fault, either through lack of knowledge in ordering his steel, or in his manufacturing methods, but in many other cases the steel manufacturer is at fault. Among the numerous causes for the steel manufacturers' troubles may be cited segregation, piping, burned steel, slaggy

ingots of certain heats. The carbon and phosphorous showing the greatest variation with sulphur follow the same tendency. This condition was particularly noticeable in heats when large additions of ferro silicon had been added in the ladle.

In the special case being cited it was found that these large additions were making the slag in the ladle acid, particularly while the last ingots were being poured. It was found this segregation was practically eliminated by adding four shovelfuls of burnt lime to the ladle just before it was full.

The effect of the acid slag in causing segregation in the ladle is shown by the analysis of slag and steel in tables No. 1 and No. 2.

Likewise in certain structural heats in which coal was used in the ladle it was noted that the last ingots were higher in carbon than the ladle test. This was found to be caused by some of the coal being held by the slag and not dissolved in the steel until the last of the heat was being poured. This condition was corrected by running slag off the ladle while tapping.

Table No. 1
ANALYSIS OF SLAG

Sample	Heat No.	Remarks	Fe. Iron	Si O ₂ Silica	Al ₂ O ₃ Alumina	Ca O Lime	Mg O Magnesia	P ₂ Phos. O ₃ Anhydride	Mn. Man-ganese
1	A.	Bath before tapping.	11.04	19.90	4.29	45.40	9.44	4.69	2.02
2	A.	On top ladle.....	7.46	25.34	4.39	40.90	6.45	3.11	8.00
3	A.	After casting slag in ladle	4.65	27.50	8.24	35.50	6.70	2.16	10.86
4	B.	Bath	11.72	20.16	3.06	42.90	9.68	4.60	1.87
5	B.	Top ladle	5.23	26.62	6.61	42.60	7.68	2.84	5.26
6	B.	After	2.40	34.00	8.48	34.40	6.00	.46	10.73
7	C.	Bath	9.78	19.90	3.83	46.20	8.99	5.70	1.66
8	C.	Top ladle	4.94	34.00	7.15	28.20	6.12	1.79	2.92
9	C.	After	3.10	33.30	7.40	28.30	6.12	.27	15.27
10	D.	Bath	10.85	19.40	3.16	45.80	8.66	5.83	1.66
11	D.	Top ladle	6.78	25.50	5.21	40.90	8.15	4.51	5.62
12	D.	After	4.46	30.30	6.62	36.00	7.32	2.91	8.79

steel, mixed steel, and various forms of surface defects caused by heating and rolling operations.

There has been and always will be controversy between the manufacturer and customer as to what constitutes injurious segregation. We will not attempt to take sides, but give the following analysis and remarks for their beneficial value only. We might add, however, there is a big opportunity for improvement on the part of the manufacturers with regards to both the quality and quantity of the steel being produced.

In the manufacture of 40 to 50 carbon steel many steel men have at times found considerable variation in the analysis between the ladle test and the last

Steel making in America has now reached the stage where poor and indifferent practice will no longer be tolerated.

Table No. 2
ANALYSIS OF STEEL

Heat No.	Test	Carbon	Silicon	Phos.	Sulphur	Mang.
A.	Ladle test.	.43	.16	.030	.035	.60
A.	Bot. ladle.	.51	.12	.045	.039	.60
B.	Ladle test.	.42	.12	.039	.037	.60
B.	Bot. ladle.	.48	.11	.056	.042	.58
C.	Ladle test.	.45	.13	.022	.031	.73
C.	Bot. ladle.	.59	.13	.047	.042	.76
D.	Ladle test.	.44	.14	.020	.029	.72
D.	Bot. ladle.	.53	.12	.042	.035	.72

Detroit Steel Casting Company Plant

**A General Description of a Most Modern Steel Casting Plant—
Improvements Have Recently Been Completed Which Modernize
the Equipment of This Plant to the Very Greatest Extent.**

By H. M. LANE.

MANY of the foundries in this country have rather a short history and can only point to work under a certain management, in some cases only for a limited length of time; but the Detroit Steel Casting Company is one which has helped make history in the steel business. Originally it was a small converter shop with one Roberts converter, but as time passed the business increased and some relatively small open hearths were added. From time to time the open-hearth equipment has been increased and the converter equipment increased and improved.

A general plan of the plant as it now exists shows that there are practically two foundries, the No. 1 shop being an open-hearth plant used mostly for the production of fairly heavy castings, and the No. 2 shop a converter unit for the production of small castings.

All of the cores for both departments are made in the coreroom shown and the dry sand molds either in the main bay of the No. 1 shop or in the side bay. They are dried in the ovens. The converter work is practically all done in green sand.

The raw materials enter the yard on the company's switch, the cars being spotted on a long track along the side of the foundry. All subsequent switching is done by the company's locomotive crane, which also does a large portion of the unloading. The sand mixing and preparation department is located between the core-room and the open-hearth melting unit and is so arranged as to reduce handling as much as possible.

Beginning with the core department we encounter a department with quite a history back of it. Formerly the cores were made in another part of the plant, occupying a space nearly twice as great as the present coreroom, and with several times the number of cubic feet of ovens. When first installed they were operated on the coke-fired forced-draft principle. Under ordinary circumstances the whole battery is heated from one firing system. This battery was one of the early installations of the Lane patent forced-draft auxiliary-air type ovens, which are now manufactured by Holcroft & Co., of Detroit, and was installed just before the war broke out. It fulfilled the requirements of the plant very nicely, but soon after the country went to war the demand for truck castings multiplied many-fold, and it became necessary to organize the core-room so as to get maximum output. The three small rack type ovens at the right of the illustration, for many months in succession, baked an average of thirty-two cars of cores every twenty-four hours, and the larger oven either baked large cars or two racks at a time. The coreroom is covered with a traveling crane, and the core racks are placed between the coremakers' benches, as shown in Fig. 1, the coremakers placing the cores directly on the racks. The crane then picks up the rack and places it on the cars in front of the ovens. The car is run into the oven, the cores baked, the car run out and the rack of baked cores transferred by the crane to the core storage department.

In some cases it is handled by a transfer car and sent directly to the folders' floor.

After these ovens had been in use for several years they were equipped with a specially designed stoker for burning soft coal. This is known as the Hare stoker and is now manufactured by the Hare Stoker & Furnace Co. of Detroit. The change from coke to stoker-firing resulted in drying the cores with fewer pounds of fuel than formerly, and with a fuel which costs less than half as much per ton. It also eliminated a large proportion of the labor of firing the ovens, as the stoker has an automatic cleaning feature.

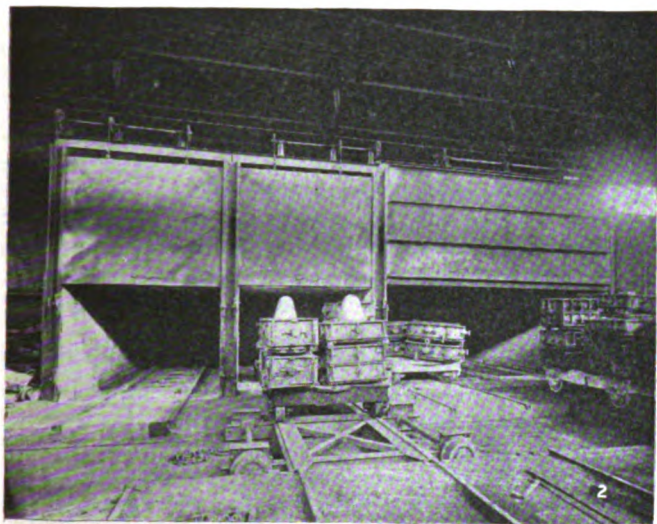
Particular attention is called to the type of coremakers' benches shown in Fig. 1. Between each two rows of benches there is a narrow sand alley, and a man wheels the sand in behind the benches and delivers it to the coremakers without interfering with their work. This room with its present arrangement has proved a splendid unit for the intensive production of foundry cores, and when the size of the coreroom and the size of the foundry are compared one will readily appreciate the fact that it must be an efficient department to take care of the entire plant.

The dry sand fold department as at present constituted is equipped with one wide oven and two narrow ovens, as shown in Fig. 2. The wide oven at the right has two parallel tracks and either takes two trains of narrow cars or the cars are bound together by a special device and large molds put on. The narrow mold oven at the left is made deeper than the others, so that it will handle locomotive frames.

These ovens are all fired from two fireboxes in a pit under the cleaning room floor back of the mold ovens. An interior view of this pit is shown in Fig. 3. This is a forced draft type pit, the air coming down through the pipe shown in the upper right-hand corner of the ceiling, the auxiliary air entering the walls about the furnaces through the small square openings shown in the brick wall at the right and left of the ovens. The air for combustion passes in through the ashpit door and is controlled by blocking the door open to any desired degree. This style of forced draft auxiliary air firepit is practically the same as was used on the core ovens before the stoker was installed, and it is the intention now to replace these fireboxes with stokers at some time in the future. The present installation, however, has been in use for a number of years, and the construction of these boxes with their aid the cooling system gives a very long life to the brick work, as well as a great fuel economy in the oven.

The converter department is an independent unit in all respects. It has its own annealing oven and its own cleaning department, and this tends to keep the two classes of castings separate. The cleaning department adjoins the side of the No. 2 shop.

The bank of closets adjoining the wash room at the end of No. 2 shop are suspended in such a way that molding goes on underneath them.



The melting unit in the open-hearth department consists of two 20-ton furnaces as shown in Fig. 4, which were built by Holcroft & Co. This illustration shows the charging platform side of these furnaces. The furnaces originally installed at the Detroit Steel Casting Company's plant were lower, and when the

two furnaces were repaired the charging platform was raised above the molding floor line. A charging machine was installed as shown, and a handling scheme for handling the scrap in the yard, making up the charges and delivering carloads of charging boxes to the charging platform. One of these furnaces was

originally operated by produced gas, and the producers are still installed, so that they can be used at any time. The other furnace has always operated on liquid fuel. At one time some years ago, when fuel oil was very high and tar cheap, this furnace was run on coal tar a considerable period with very satisfactory results, but oil is simpler to handle, and at many times the market is such that tar cannot be obtained so as to compete with the oil. At present the melting is being conducted with oil.

The main bay of the foundry is equipped with a number of traveling cranes of various sizes which enable them to handle any size casting which comes within the limits of their pouring ability.

Fig. 4 shows one of the main bay cranes over the oven roof.

A general view of a portion of the main bay of the open-hearth foundry is shown in Fig. 5. This view also illustrates a method of skidding molds which is commonly used in this plant. Two pieces of railroad iron are clamped together with suitable spacers and provided with links at the end. Upon these are piled the molds as they come from the molding machine. The entire skid is then taken to the pouring floor, where it is shown in this illustration. After pouring the skid of molds is taken to the shake-out floor, and later the skid with the empty flasks and bottom boards on it is returned to a position near the molding machine. In this illustration the melting unit is on the right and the dry sand molding department on the left.

The very large castings are cleaned under the main cranes in the No. 1 shop, and a large annealing oven is located under this crane, where large castings can be annealed. The smaller open-hearth castings are cleaned in either one or two cleaning departments. One, which is mostly devoted to railroad work, is located in the same side bay that contains the core-room and the molding units, and the other, devoted mostly to jobbing castings, is located in the opposite side bay adjoining the dry sand ovens. The castings from these two departments are shipped at the end of the building. Practically all small castings that are to be shipped in carload lots are cleaned in the bay adjoining the felting unit, and provision is made for switching a car into this department under the crane. Provision is also made for shifting a car into the main bay of No. 1 shop and loading heavy castings. The product of the other cleaning room is practically all trucked to local customers.

At the end of the plant adjoining the annealing furnace there is a sand conveyor pit and refuse hoppers on the outside arranged to take care of outgoing sand and to recover a portion of this for reuse in the plant.

There are a series of grinders in the cleaning departments. In the case of the large swinging grinders the castings are generally mounted on a wooden frame carried on rollers, and the workman rides on this frame and moves the casting back and forth under the wheel as he grinds it. This gives him thorough control of his work.

Fig. 6 shows a portion of the battery of saws and other tools used for cutting off heads and risers in one of the cleaning rooms. In this illustration attention is called to the charging box standing in the foreground. These charging boxes are placed at intervals through the cleaning department, and all heads and smaller waste material thrown into them, care being

taken to see that each grade of material is kept by itself. These boxes are then transferred by the crane to a car at the end of the shop and by it transferred to the metal department adjoining the open-hearth building.

Attention is called to a number of features in connection with this plant which have been developed for the advantageous handling of the property. The pattern shop and main pattern vault are located in a separate building adjoining the No. 2 shop, and yet at the same time in such a position that these patterns are readily accessible to the molders on either of the molding floors. An auxiliary pattern storage for outside patterns and patterns that are rarely used is located at the opposite end of the plant.

As already stated, fuel oil is used, and for the storage of this a double reinforced concrete tank has been installed near the track entrance to the yard, and this tank holds 180,000 gallons of oil. This tank is designed to carry 10 to 12 feet of coal piled on top of it.

The plant formerly had its own power plant, but at present the boilers are used only for heating purposes, and the electric current is obtained from the Detroit Edison Company.

For the last few years the H. M. Lane Company has acted as the engineers for the Detroit Steel Casting Company, designing certain special equipment for them and collaborating with them in carrying out the various improvements and extensions which have been necessary.

PITTSBURGH CHAPTER OF THE AMERICAN SOCIETY FOR STEEL TREATING

On August 23, what was termed the Council of the Pittsburgh Chapter of the American Society for Steel Treating, met at dinner at the Hotel Chatham for the purpose of discussing plans for the coming year. This Council was made up of about 20 including the various officers and members of committees. Dr. C. M. Johnson, recently elected chairman of the Chapter is ambitious to make it the biggest year the Pittsburgh Chapter has ever known and accordingly has been holding various committee meetings to complete arrangements. It was decided that the entertainment committee should provide some special entertainment feature for each regular meeting.

An unusually prominent and interesting group of speakers has been secured for the coming meetings which will be held on the first Tuesday of each month. At the first meeting, September 6, Prof. F. F. MacIntosh of Carnegie Institute of Technology will speak on "The Metallurgy of Iron and Steel." This meeting will be in the Hotel Chatham and will be preceded by a dinner at 6:30 and the special entertainment feature mentioned above. It is requested that any one desiring to attend the dinner, remit to Mr. D. W. McDowell, secretary-treasurer, 203 Conniston Avenue, Pittsburgh, Pa., a check for \$1.50.

The October meeting will be addressed by Mr. Chas. E. Carpenter, president of the E. F. Houghton Company, a speaker who is nationally known. His subject will be "Individualism vs Socialism." In November, Prof. Albert Sauveur of Harvard will speak on the Heat Treatment of Steel. In December, Prof. H. F. Moore of the University of Illinois will discuss Fatigue Testing and Resistance of Materials.

U. S. Government Air Nitrate Plant No. 2 Muscle Shoals, Ala.

War and Peace Time Purposes of Its Construction—Future Limitations as a Competitor of the By-Product Plant as a Producer of Ammonium Nitrate for Fertilizer or Explosives.

By GEO. B. CRAMP.

A SUBJECT under this headline might appear somewhat out of place in these columns were it not for the growing interest of Blast Furnace and By-Product Coke plant operators and technicians in the subject of commercial farm fertilizer production as side lines or by-products of their basic operations.

It is not widely known that, at blast furnaces located in certain localities where high phosphorous ores are mostly available, a by-product of their operation is their high phosphorous slag which with but little treatment is made available as a phosphate fertilizer.

At other furnace plants where ores high in potash are mostly used, a rich return is realized in the recovery of potash, which is readily separated from the blast furnace dust carried out of the furnace by the gases. It is the possibilities along these lines that have given such impetus to development of the electric dust precipitators, descriptions of which have appeared from time to time in this periodical.

Blast furnace gas itself is composed of a high percentage of nitrogen, but it is not in such combination with hydrogen that it forms ammonia which would in turn render its recovery possible. It is highly improbable, however, that nitrogen will ever be recovered from blast furnace gas, at least on an economic or commercial basis; but the inability to produce nitrogen at the blast furnace is more than compensated for by the by-product coke plant, which in good blast furnace practice today may be considered an essential adjunct.

Not all blast furnaces produce either phosphate or potash, but all by-product plants usually produce nitrogen in the form of ammonium sulphate. It may be generally stated, however, that the blast furnace and by-product plant together produce all these three elements necessary to plant growth, development and maturity.

Neither one of these elements alone is a balanced fertilizer; and all three are usually supplied in various proportions for different crop requirement, but in scientific crop management it is first determined by soil test which element is lacking, and which element is most needed in the production of the particular crop to be grown, and the requisite element then applied in proper amount.

One other consideration of soil conditions is necessary in the selection of fertilizers, namely, the determination of the acid or alkaline content. By use of litmus paper, soils are found to be either acid or alkaline; but if no discoloration of the paper is indicated the soil is in neutral condition, that is, the acid that may be present is neutralized by a sufficient amount of alkali so that neither show a predominance.

Some crops do well in acid soils and show poor results in soils too highly alkaline and vice-versa. This accounts for the general opinion that some crops do much

better in certain parts of the country than in others where climatic conditions are equal. This idea is erroneous, however, as all things being equal, all crops do equally well under neutral soil conditions.

The soils of eastern, east central, and southern United States were acid in their virgin state because acids are given off in the decomposition of the vegetable matter which usually forms the top or surface soil in these sections. After some years of cultivation, the acid reaches out of the soil to such a degree that the lime stored up in the decayed vegetable would cause a reaction to the alkaline state. After continued cultivation this lime is exhausted and the soil reverts again to the acid state because of the acids produced by decomposing roots left in the ground after crops are removed or from any other vegetable decay.

The soils of western, northwestern and southwestern United States are usually alkaline in their virgin state and tend to remain so if not irrigated or influenced by applications of fertilizers of acid base and by continued crop culture.

The best soil conditions being the neutral state, acid soils may be brought to this condition by application of lime or fertilizers having a lime base, while alkaline soils are best neutralized by applications of acid fertilizers and by growth and turning under of green crops which form acid in decomposition.

In the growth of all crops large amounts of nitrogen are required. As most commercial nitrogen fertilizers are acid in their ultimate influence on the soil, they are well adapted to alkaline soils such as predominate in western United States; but where these acid base fertilizers are applied to acid soils such as predominate in eastern United States, they simply add to the natural acid tendency of these soils, making frequent applications of lime necessary to maintain neutral soil conditions. From this it will be seen that the application of nitrogen fertilizer, with a lime base, to an acid soil would at once add the desired fertilizing and neutralizing elements and avoid overburdening the soil with excess acidity.

Such a lime-nitrogen fertilizer, called Cyanamid was being manufactured before the late war by the American Cyanamid Company of New York City with a plant at Niagara Falls, New York, where hydro-electric power entering largely into the process, is obtained at the lowest rates.

This company operated under a patented process originating with Scandinavian interests, where the process has proven a commercial success due to low hydro-electric power costs, and no competition from by-product fertilizers. The main source of nitrogen fertilizer supply before the war was Chilean sodium nitrate, or saltpeter, of which there are large but limited supplies in that country. During the war practically all imports of this

nitrate went into the production of high explosives, one of which was the much mentioned T. N. T. or triple nitrated toheol.

As the United States government had neither influence nor control over any part of the Chilean nitrate supply, and as it was desirable to release all shipping possible, for cross sea service, it was finally decided to build a nitrate plant which would help solve the shipping problem and at the same time make this country entirely independent of all outside sources of nitrate supply.

The process selected was the above mentioned Cyanamid Process. A corporation called the Air Nitrate Corporation, a branch of the American Cyanamid Company, was organized under government supervision to build a large plant at Muscle Shoals near Sheffield in northwestern Alabama on the Tennessee river, where there is eventually to be built a large dam across the river and a hydro-electric plant, by the government. As an emergency measure, however, a large steam power plant was built in connection with the Air Nitrate Plant to immediately supply the requisite electric energy.

Besides being able to turn out large quantities of ammonium nitrate for war use, by adoption of the Cyanamid Process it would be relatively easy to convert the plant in peace time to fertilizer manufacture, and as both lime and acid-base nitrogen agricultural needs could be met, and at a supposedly low cost considering the cheap labor, and raw material costs and eventual low hydro-electric power costs, which the location of the plant made accessible, while nitrogen, so important to the process, is secured from the atmosphere; but in this respect no particular location has any advantage over another.

Without attempting to go into costs of producing ammonia or nitrogen fertilizers by the Air Nitrates Cyanamid Process compared to the By-Product Process, an outline descriptive of each process will here be given, followed by a brief discussion as to future possibilities of the latter process as a cheaper source of both peace time fertilizer, or war time explosive production.

Cyanamid Process—Carbide Material Department.

The first step in the production of Cyanamid is to produce calcium-carbide; the identical commercial product used in the generation of acetylene gas used in illuminating systems, and in welding processes.

In making carbide, limestone of good quality and high carbon coke are received at a raw materials building where they are stored in bins and fed to conveyors. The limestone is conveyed to large rotary kilns where it is burned to quick lime which is the same commercial product used in mortar and plaster in building construction. The fuel used in this operation is powdered coal.

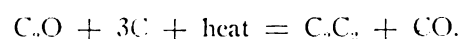
The coke is conveyed to rotary driers where all moisture is driven off. The quick lime and coke are then conveyed to storage bins awaiting use in the following process.

Carbide Furnace Department.

In this department, lime and coke are burned in a stationary (non-tilting) open top electric furnace, the result of the operation being calcium carbide.

Lime and coke are conveyed from the storage bins, and after being mixed in proper proportion are conveyed to small bins over the charging floor at each electric furnace. The mixture is gradually fed into the furnace from the charging floor by hand.

Under the influence of the pure and intense heat of the electric arcs of the electrodes, which are suspended in the center of the open top furnace, the lime combines with the coke forming a molten mass giving off carbon monoxide, which burns as it leaves the molten materials, and passes off as carbon dioxide. The chemical reaction taking place in the furnace is



When sufficient molten material is available the furnace is tapped at the side near the bottom through a hole which remains plugged with the chilled carbide material. Tapping is accomplished by burning or melting this carbide to a molten consistency when it will flow out of the tap hole permitting the molten bath, back of it, to flow out into cast iron boxes on cars called chill cars.

The chill cars with the hot carbide are delivered to the cooling room of the Carbide Mill Department the next department in order of the sequence of operation.

The Carbide Furnace Department is equipped with an electrode repair shop where the carbon electrodes for the carbide furnaces, are prepared and fitted with water cooled holding clamps. The electrodes are assembled three in a group. Wire netting is placed about each electrode and covered with a layer of heat resisting material. The electrodes are then set into a semi-muffle type heating furnace—coal fired—and the protective coating baked on under slow heat.

Carbide Mill Department.

Here the cooled carbide blocks or pigs are removed, after cooling, from the chill car boxes, and crushed in jaw crushers. After this operation the material is conveyed to ball mills where it is further reduced, and thence to tube mills—which are rotary cylinders containing rolling metal rods which accomplish the pulverizing of the carbide. The milling operations are conducted in an atmosphere of pure nitrogen secured from the Liquid Air Department to be described in turn. The nitrogen is piped under pressure into the mills thus displacing all air and avoiding explosion of acetylene gas which might form from contact of fine carbide dust with moisture of the air. Nitrogen uncombined being an inert—non-explosive—gas; the chance of such accidents are reduced to a minimum.

Nitrogen or Liquid Air Department.

Pure nitrogen gas being required in the foregoing operation and in even greater quantities in further operations of the process, this gas is supplied by the Liquid Air Process which begins with intaking air from the atmosphere and forcing it through scrubbers for removal of solid and gaseous impurities. The air is then compressed to a pressure of 600 pounds per square inch and then by rapid expansion the moisture and liquified oxygen are fractionated from the remaining pure dry nitrogen which is piped to the various departments as needed.

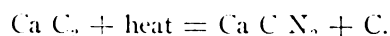
Lime—Nitrogen or Cyanamid Department.

Nitrogen gas and milled carbide are combined, in this department, by the electric arc; the result being Cyanamid which must simply be milled to produce the commercial product. This is such a nitrogen fertilizer with a lime base as is referred to in the earlier part of this discussion on fertilizers.

In the operation of producing Cyanamid, cylindrical paper containers are set into vertical cylindrical ovens. These containers are filled with milled carbide by a traveling hopper car running over the ovens, in a similar man-

ner to the method of charging coal into the coke oven.

Suspended through the center of the carbide is a thin carbon electrode with proper electrical connections, and after filling, the cover is fastened onto the oven and the electric current applied. When sufficiently heated, nitrogen gas is introduced into the oven through proper pipe connections and the absorption of nitrogen gas by the heating carbide begins to take place. One pound of nitrogen gas is thus absorbed by each four pounds of carbide used and the chemical reaction taking place is



When absorption of nitrogen gas by the carbide has ceased to continue, the electric current and gas are turned off and the hot mass, which has solidified in the process, is removed in a cylindrical shape, and taken to the next department for milling.

Lime—Nitrogen Mill Department.

The cooling, crushing and milling of the lime nitrogen takes place here.

No great care is required in keeping the material dry while cooling as is necessary with carbide, nor is it necessary to mill this material in an atmosphere of nitrogen gas, as it does not readily combine with moisture to form acetylene gas.

Hydrating Department.

In this department powdered lime nitrogen from the mill department, has added and stirred into it just sufficient water to drive off the last traces of acetylene gas which may be generated from any free carbide that may chance to remain in the lime nitrogen.

From this department the hydrated lime nitrogen is conveyed to the ammonia gas department if it is to be converted to ammonia gas and ultimately ammonium nitrate, but the material as it leaves the hydrating department is refined commercial carbide or lime nitrogen fertilizer and is ready for shipment, sale and use as such.

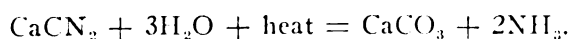
If ammonium nitrate is to be produced from the cyanamid the process is continued.

Ammonia Gas Department.

Hydrated lime nitrogen is brought from the hydrating department to this department.

In a large vertical cylindrical vessel, called an autoclave partly filled with water, there is added in proper proportions, lime nitrogen and caustic soda. The openings are then tightly closed, and while the solution is being stirred, steam is introduced and the generation of ammonia gas begins.

After starting the reaction it generates its own heat. This reaction is



After all the ammonia available in the charge of lime nitrogen has been recovered, the remaining sludge and liquor are drawn off at the bottom of the autoclave, and run through rotary filters where the solid materials are separated from the liquor.

The liquor is pumped to storage reservoirs and used over again, and the slugs is pumped to some point or disposed of nearby.

Thus the coke and lime have simply served to absorb nitrogen gas until it is brought to this point in the process where it combines with hydrogen to form ammonia gas.

Nitric Acid Department.

About half of the total ammonia produced in the ammonia gas department is required for the production of nitric acid. In this process the ammonia gas is mixed with clean scrubbed air and the mixture passed through electrically heated platinum gauze catalyzers. By this means, ammonia is combined with air forming nitric oxide. This gas is carefully cooled—first in high temperature coolers, and then passes on to absorption towers where it is absorbed by water sprayed again and again through the towers until it has become 40 per cent nitric acid, and on reaching this strength is stored in tanks to be later used in the neutralizing process.

Nitrate Department.

Neutralizing the nitric acid from the foregoing operation is accomplished in this department by combination of the remaining ammonia gas—not used in production of nitric acid—with that acid, the result being a salt solution which is 45 per cent ammonium nitrate. This solution is then evaporated, crystallized and dried, after which it has the appearance of coarse salt. In this form it is shipped or use in the nitration of toluol, manufacture of other explosives, or as a powerful ammonia fertilizer of acid base.

General Comment.

Compared to the constructive by-product process of ammonia and other by-products removed the cyanamid ammonium nitrate process is destructive in that power and materials not originating from economic processes of manufacture, or as by-products of operation, are continually consumed to produce the ultimate product. In the by-product process new products result from each step in the process of cleaning the gas, of which there is a large surplus after fuel for ovens and power for plant operation is deducted.

It will be noted that in the production of carbide, coke is used. This same coke may have been produced in a beehive coke oven, in which case the valuable gas and other volatiles, including ammonia, have been lost, and after this serious loss it is used to absorb nitrogen again, a gas it once contained in easily recovered form, in its raw state, or as coal.

The coal that is used in this process for power and heating purposes also loses its valuable volatiles in combustion and but a small part of its total heat value finds its way into the product being manufactured.

An outline of the ammonia recovery process of the by-product plant follows.

By-Product—Processes of Ammonia Recovery.

In producing coke by this process, the coal is baked in an oven at a temperature sufficiently high to drive off the greater part of the gas and other volatiles which are properties of raw coal. The residue, after these gases have passed off, is carbon or coke. The gas and volatile are drawn from the oven's through tubular coolers in which the gas is brought to a temperature sufficiently low to bring down tar and some ammonia, which exists in weak liquor. The tar and weak ammonia liquor are mingled at first, but the two are readily separated in properly constructed tanks that automatically accomplish separation by gravity. The ammonia liquor is then run through a free still where the free ammonia gas existing in the liquor is driven off in vapor form, leaving certain

solid deposits contained in the liquor, to form within the still. After the free ammonia has been released by heat, the remaining ammonia liquor is run through a fixed still where the ammonia gas is released by use of comparatively small quantities of lime water. The ammonia gas from both stills finally pass out a common outlet, and may then be condensed to form aqua ammonia, or be passed on to the saturator where ammonium sulphate is produced by the so-called direct process later described. The recovery of ammonia by distillation is known as the indirect process.

The direct recovery of ammonia is accomplished by passing the gas—after it has passed through the coolers—through a saturator in which the gas is caused to bubble through a bath of weak sulphuric acid solution. The ammonia, coming in contact with the acid, is neutralized and forms crystals which settle to the bottom of the saturator and are then removed and dried. This is commercial ammonium sulphate and may be sacked and shipped, for use as nitrogen fertilizer of acid base.

This form of nitrogen is produced so simply and inexpensively, compared to many other forms of manufactured nitrogen fertilizers, that it will doubtless be able to always compete favorably with, or undersell them.

It would be desirable if some of the ammonia, produced in sulphate form, could be combined with lime to form a nitrogen fertilizer of lime base as is done in the cyanamid process; but the same results may be obtained with acid base fertilizer on acid soils if the acidity is held in check by proper applications of cheap commercial lime, which practice will be less expensive than the use of the higher priced lime—nitrogen fertilizers.

Ammonium nitrate production by the by-product process, for use in explosives, is a future war time possibility, inasmuch as the large amount of ammonia gas produced by the indirect process is available for this purpose.

A possible arrangement for accomplishing this would be the installation of a nitric acid plant such as is described in the cyanamid process, at about half of the by-product plants, and at the remaining plants neutralizing and crystallizing plants might be installed. Ammonia gas from the stills would be converted to nitric acid at the nitric acid plants and the acid shipped to a plant having the neutralizing equipment. Here the gas from the stills would be combined with the nitric acid, then evaporated, crystallized and dried—as in the ammonium nitrate process—the product being pure ammonium nitrate.

During the war this arrangement was not easily possible on a large scale as much of the present by-product plant capacity was not in existence and was rather widely scattered.

However, the rapid expansion of the by-product coke industry, which will, in the not far distant future, include all coke now produced by the beehive ovens, would put the by-product plants in a fair position to furnish large amounts of ammonium nitrate for explosive manufacture—in the event of a future war—and at a cost much less than, no doubt, by any other known and practicable process.

During the war successful efforts were made in the conversion of ammonium sulphate—as produced by the direct ammonia recovery process at the by-

product plant—to ammonium nitrate. With some improvement yet to be made in the chemical purity of the product, the results obtained may be said to be satisfactory. With this process there is also a future possibility of turning the whole ammonia output of the by-product into ammonium nitrate.

Thus it may be possible through our by-product plant development to secure our country's entire independence of foreign sources of ammonia supply, in the future, or as long as our supply of raw coal shall last.

Incidentally the by-product plant would then produce the two principal components of tri nitro toleol, namely the ammonium nitrate and toleol requisite in its production; the by-product plant, even during the late war, having been the source of large supplies of toleol.

ELECTRICAL ENGINEERS' CONVENTION

The fifteenth annual convention of the Association of Iron and Steel Electrical Engineers will be held at the La Salle Hotel, Chicago, September 19-24, 1921. The sessions and exhibits will be held in the Municipal Pier.

Papers, particularly interesting to electrical engineers of steel plants will be presented. The authors of these papers are men who have devoted years to the study and operation of electrical applications and steel making processes; they are men well qualified to discuss the particular subjects allotted to them and are engineers known throughout the iron and steel industry.

The authors are as follows:

R. B. GERHARDT, Electrical Superintendent,
Bethlehem Steel Company, Sparrows Point, Md.

R. D. COUSINS, Electrical Engineer,
Illinois Steel Company, Gary, Indiana.

G. R. McDERMOTT, Assistant Engineer,
Illinois Steel Company, South Chicago, Ill.

W. N. FLANAGAN, Steam Engineer,
Ohio Works, Carnegie Steel Company, Youngstown, O.

F. B. CROSBY, Electrical Engineer,
Morgan Construction Company, Worcester, Mass.

A. C. BUNKER, Electrical Engineer,
Crocker Wheeler Company, Ampere, N. J.

A. M. MacCUTCHEON, Designing Engineer,
Reliance Electric & Engineering Co., of Cleveland, O.

E. T. MOORE, Electrical Engineer,
Halcomb Steel Company, Syracuse, N. Y.

F. W. CRAMER, Engineer of Tests,
Cambria Steel Company, Johnstown, Pa.

Papers will also be presented on the following subjects: Education, Standardization, Safety, Electrical Development in Steel Mills. The chairman of these respective committees will deliver these subjects.

In connection with the convention there will be also be the Exhibiting Feature.

Practically all the manufacturers of electrical products will be represented.

Analysis of Wholesale Electric Costs

Explanation of Rates and Methods of Reducing Power Costs to a Minimum.

By F. M. VAN DEVENTER.

ARTICLE III.

THE general economic principle upon which all rates for power and similar utilities are based embodies two principles—first, that the gross revenue from all consumers should cover all costs of producing the utility, including interest on the investment, insurance, taxes, depreciation, etc., plus a "fair" return in the way of profit on the investment; second, that the distribution of the gross cost should be such that the various consumers of the utility will pay for the service rendered them in proportion to their just part of the total cost.

The total cost of supplying a utility is composed of two classes of charges, namely the fixed and operating charges. For a given plant, the fixed charges are practically independent of the quantity of the utility produced, and include interest on the investment, insurance, taxes, depreciation and obsolescence, etc., which continue uniformly whether the plant is operating at full capacity or whether it is standing idle. The operating charges consist of the cost of raw materials, such as fuel, water, lubricants and chemicals, and also labor, repairs, etc. These, in a general way, vary in direct proportion to the quantity of production of the utility. This distinction between fixed and operating charges is just as important in the construction of utility rates as it is in the determination of the selling price of any commodity such as we buy daily in the open market, and its bearing on electric rates will appear in this analysis.

Systems of Rates.

Electric power rates may be considered in two different classes, namely, the "postal plan," and the "sliding scale" form of rate. The postal plan is the simplest form and was at one time in quite general use for all utilities and is still used almost exclusively for the sale of gas and water. Essentially the principle of the postal plan is that just as a two-cent stamp will deliver a letter a few blocks from the mailing point, or many hundred miles from that point for the same cost, so a kwh might be sold to all consumers at a definite fixed cost per kwh, regardless of the many and varied con-

ditions which might be imposed upon the producing company in delivering this unit of energy.

This plan of selling electric power was very satisfactory a number of years ago, when the total power load consisted of incandescent lamps, and the various consumers used their lights during the same hours of the day, and no particular consumer was imposing any hardship upon the producing company any more than another consumer; hence it was logical to charge each consumer in proportion to the amount of energy which he consumed.

The postal plan of rates, however, has a number of very important shortcomings when applied to modern electrical loads, and on account of this fact the plan does not satisfy the second requirement of the general economic principle previously stated, inasmuch as it costs the utility company

considerably more to deliver a kwh to some consumers than it costs to deliver another kwh to other consumers. The shortcomings of this plan prompted the development of the sliding scale type of rate. The various controlling conditions will be considered at length before showing how they are incorporated into a sliding scale system. They are: maximum demand, load factor, minimum charge, power factor, off-peak and limited service.

CONDITIONS AFFECTING POWER RATES

Maximum Demand.

The meaning of maximum demand will be most clearly understood if considered in the following manner. The instantaneous demand is the number of kw being drawn from the line at any definite instant. The interval demand is the average number of kw being drawn from the line during a specified interval of time, e. g., five minutes or fifteen minutes, and is equal to the arithmetic average of the instantaneous demands during the time interval. The maximum demand is the value of the greatest interval demand which occurs during the billing month.

The Duquesne Light Company's Schedule "F" bases their rate upon the maximum demand for any 15-minute interval, and they determine this quantity from a recording demand meter which records the interval demand for each 15-minute interval of the month.

Various modifications of the preceding method of determining maximum demand may be made. For example the West Penn Power Company determines the maximum demand (kw) for a five-minute interval

*SYNOPSIS: In the two preceding articles (June and July issues) graphic charts were presented, representing the Duquesne Light Company's schedule "F" and the West Penn Power Company's schedule "J" for wholesale power. The use of the charts for the purpose of checking power bills was demonstrated. In the present article, the "demand plus energy" system of rates upon which these schedules are based, is explained; and the use of the charts for the purpose of studying methods of reducing power costs is discussed.**

*Note—While the analysis made in this article is based upon the two particular schedules named, the general principles apply to any power rate of the same general character. A reprint of the three articles, including both charts, may be obtained from Blast Furnace and Steel Plant, or from the author, Box 132, Pittsburgh, Pa., for \$.....

and adds a certain portion of the maximum instantaneous demand occurring in the billing month, under certain conditions. For this purpose they obtain a complete monthly record of load with a curve-drawing watt-meter. From this record they determine the maximum five-minute interval demand, and if the maximum instantaneous demand is greater than 150 per cent of the maximum interval demand, then one-half of the excess above 150 per cent of the maximum interval demand is added to the maximum demand to obtain the (kw) billing maximum demand.

It is, therefore, seen that the maximum demand is a measure of the capacity which a consumer "demands" and the producing company must provide equipment of sufficient size to serve this, and every other customer accordingly. It is obvious that while two customers might consume an equal number of kwh per month, one customer might have a maximum demand several times greater than the other, and since the producing company must provide more costly transformers and feeders for this customer's use (on account of the greater capacity necessary) and must have more reserve capacity at the generating station for him, it is only fair that the customer with the high demand should pay more for his power in order to cover his proportionate share of the fixed charges on the producing company's equipment. (It is well to point out in this connection that, if the two customers mentioned were generating their own power, the one with the high maximum demand would require a larger power plant than the other, and his power cost would be correspondingly higher.) It is obvious that the "postal plan" would not be equitable, as it would make the customer with a low demand pay a part of the fixed charges on the more costly equipment which was installed for another customer.

Load Factor.

Load factor is defined in the standardization rules of the A. I. E. E.† as "The ratio of the average power to the maximum power during a certain period of time. The average power is taken over a certain period of time, such as a day, a month, or a year, and the maximum is taken as the average over a short interval of the maximum load within that time." As applied to the present case, the basic "period" is a "billing month" and the "short interval" is 15 minutes for Duquesne schedule "F," and five minutes for West Penn schedule "J."

The effect which load factor has upon power rates is similar to the effect of maximum demand, assuming two customers with similar loads and equal maximum demands, the fixed charges on the equipment which the producing company installs for each are equal. But if one customer operates his plant 600 hours per month (high load factor) and the other one operates only 300 hours per month (low load factor), the latter should pay a higher unit rate for his power than the former, because his share of the fixed charges is spread over a smaller block of energy (kwh). The energy charge portion of the unit cost would be equal for the two customers. (Again, if the two consumers were producing their own power, their fixed charges would be equal and the one with low load factor would spread his charges over a smaller block of energy, and his unit costs would be higher than those of the other plant with high load factor.)

†American Institute of Electrical Engineers.

The postal rate would not be equitable in this case, as it would charge both customers the same unit rate, and the customer with high load factor would be paying a part of the fixed charges on equipment used by the other customer.

Minimum Charge.

The discussion of load factor leads logically to the subject of minimum charge. The analogy of the isolated plant serves well again.

Suppose a manufacturing company operating their own power plant of 10,000 kw capacity, is forced by an industrial depression to suspend operations. The power plant will operate at almost zero load, furnishing energy only for lights, small machinery used for repairing, etc., and a reserve boiler unit under steam for fire pumps or other emergency. But the fixed charges on the investment of, say, \$1,250,000, will continue, and they will be just as high as they would be if the plant were producing 5,000,000 kwh per month. The owners would not salvage their plant during their shutdown in order to save the fixed charges, as the plant must be had intact when business resumes.

Power producing companies in the Pittsburgh and other industrial districts are affected in just this manner by the present industrial depression. Many of their largest, as well as small consumers, have ceased operations, and since they use power in small packages or for emergency purposes only, they pray to be relieved from the "imposition" of the minimum charge, for which they are billed. But the producing company must continue to pay the fixed charges on the equipment installed, and must also hold their equipment in readiness to serve their customers the instant the customer closes his switch, so it is no more than fair to charge the consumer for the fixed charges on the equipment which is held for his use by the producer.

The West Penn minimum charge clauses were quoted in their contract in Article II. The Duquesne Light Company's clause was also quoted in Article I, but an interesting fact may be pointed out in this connection. The Duquesne schedule establishes the minimum charge as equal to the demand charge on 75 per cent of the connected load. Notice also that when the demand is not measured, it is taken as 75 per cent of the connected load. This means that the minimum charge is exactly the same as the demand charge, which is designed to defray the fixed charges, with a zero energy charge added.

Power Factor.

A real understanding of power factor requires a thorough knowledge of the characteristics of alternating currents, but it is hoped that the following explanation will serve the purpose of this discussion.

Low power factor has three objectionable effects, viz.: (1) reduction of capacity, (2) increased losses, and (3) voltage regulation.

1. In the case of an alternating current, the actual current flowing in the circuit may be considerably greater than that corresponding to the power being transmitted. The ratio of the power transmitting current to the actual current is called "power factor." The excess current, which always accompanies low power factor, is caused by induction motors, transformers, and other induction apparatus, and from the definition of power factor, it is seen that as the power factor

decreases, the excess current increases. Now, since the capacity of any kind of electrical power equipment is limited by the maximum safe current for which it was designed, it is seen that where the excess current exists (i. e., where the power factor is low) all the equipment must be built oversize in order to carry rated load. This is shown in the following table:

Table 1.			
Power Factor	Actual Available Capacity	Required Rated Capacity	Relative Transmission Loss
100%	10,000 kw	10,000 kva	100%
90	10,000	11,100	123
80	10,000	12,500	156
70	10,000	14,300	204
60	10,000	16,700	279
50	10,000	20,000	400

The last line of this table indicates that if a generator or other equipment is to carry 10,000 kw at 50 per cent power factor, it must be as large as though it were to have a capacity of 20,000 kw at 100 per cent power factor. Or, inversely, if a piece of equipment is designed for 10,000 kw at 100 per cent power factor, but is operated at 50 per cent power factor, its available capacity is reduced to only 5,000 kw.

2. The principle loss which occurs in all electrical machinery and circuits is the heat loss, and this loss varies as the square of the actual current flowing. This loss, then, varies inversely as the square of the power factor, and is indicated relatively in the last column of Table 1. For instance, the heat loss at 50 per cent power factor is four times as great as at 100 per cent power factor.

3. Satisfactory voltage regulation is much more difficult with low power factor, and as a result of this fact, other equipment, not only in the same plant, but also that in use by other customers on the same feeder, suffers from bad voltage regulation during large power surges under low power factor.

In view of the three reasons given, it is only fair to penalize consumers whose loads have low power factor, because a greater investment is made in equipment which the power company must install for their use, and they should pay the additional fixed charges thereon as well as for the increased transmission loss. The postal plan is not equitable in this case, since under such a rate all consumers would pay the same unit rate for power, regardless of their power factor.

Essentially, the power factor penalty correction is made by dividing the metered demand by the actual power factor, and multiplying by unity or by some other power factor which is established as "permissible." Thus, the lower the power factor, the higher the billing demand, and the higher the cost per kwh.

Off-Peak and Limited Service.

Fig. 1 shows a representative daily load curve for a central station serving an industrial district. The average load for this day was 51,000 kw, and the maximum load was 71,000 kw; hence the load factor (daily) was $51,000 \div 71,000 = .72$ or 72 per cent.

It will be noted that the peak load occurs from 7 A. M. until 5 P. M., except for the noon-hour slump. The central station must have sufficient capacity installed to supply the peak demand, with a certain amount of spare capacity for emergency, etc., and the fixed charges must be paid on the total equipment installed. Now if the producer could build up the load during the off-peak hours, the cost of producing that

off-peak energy would be little more than the operating costs, as no additional equipment would be necessary. In other words, the daily load factor on the station would be increased. The producer can, therefore, afford to offer some inducements to his customers in the way of reduced rates for off-peak energy, in order to make more efficient use of his equipment.

As steel mills cannot advantageously avail themselves of off-peak service, the subject will not be discussed at length here, but where such service can be used, a considerable reduction in power cost can be effected.

Limited service, which is available only for small consumers under West Penn schedule "J," also offers reduced rates. Such customers are entitled to service during peak hours as well as during off-peak hours,

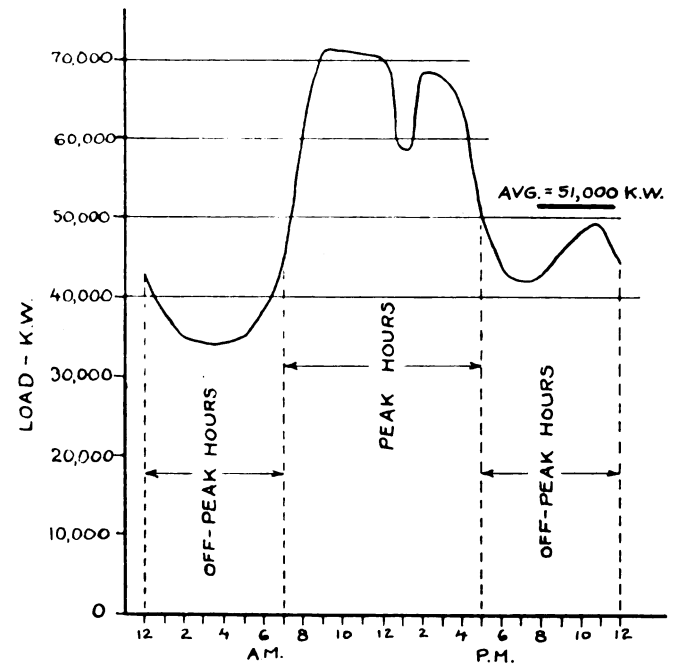


Fig. 1.

but the producer may, at his option, suspend service to limited consumers in case of breakdown or other emergency when the normal operation of the producer's plant is hampered.

THE SLIDING SCALE RATE

From a consideration of the preceding factors, it is seen that the most equitable form of rate must take into consideration the amount of equipment installed by the power company for a given consumer's use, as well as the amount of energy which he consumes. The result is some form of sliding scale rate. Various forms of this type have been proposed and are in use, each attempting to provide a reasonable return on the investment, after defraying the manufacturing costs, and at the same time to distribute the total cost of operating the utility equitably among the various consumers. Sliding scales may be divided into three general types:

a. The block system, which consists of two or more blocks of energy with different rates applied to each block. The blocks may be established by a given number of kwh, or by a number of hours' use of the consumer's maximum demand. The West Penn wholesale rates are of this type, the first block being equal to

70 hours' use of the consumer's maximum demand and the second block being the remainder of the total energy consumption.

b. A demand charge, obtained by multiplying the consumer's demand by a fixed rate per kw of demand; plus an energy charge, obtained by multiplying the quantity of energy consumed by a fixed rate per kwh.

c. A combination of the above systems consisting of a demand charge and an energy charge, the latter made up by applying different rates to two or more blocks of the energy consumed. The Duquesne Light Company's rates are of the latter type.

Graphic Representation of Sliding Scale Rate Schedules.

Having enumerated and discussed the factors which establish the rates for a sliding scale, it will be instructive to see by means of reference to the charts, what effect these factors have in Duquesne schedule "F" and West Penn schedule "J."

Maximum Demand.

(Refer to chart for Duquesne schedule "F.")

By noting the intersections of the vertical line at 750,000 kwh with various demand lines, it is seen that the corresponding costs for this quantity of energy are:

Table 2.

Maximum Demand	Cost for Month	Cost per kwh	Load Factor	Penalty per Month (Above Cost at 100% L. F.)
1,027	\$ 8,100	\$.0108	100%	\$ 0.0
1,284	8,600	.0115	80	500.
1,711	9,500	.0127	60	1,400.
2,570	11,100	.0148	40	3,000.
5,140	16,200	.0216	20	8,100.

From the table it is seen that the cost of 750,000 kwh may be anything above \$8,100, depending upon the maximum demand; the cost at 5,140 kw demand being almost double the cost at 1,027 kw demand. The last column shows the "penalty" assuming the ideal condition to be 1,027 kw demand, which corresponds to 100 per cent load factor and which would require that this quantity of power be drawn continuously from the line throughout the month (730 hours).

All the quantities tabulated in Table 2 may be obtained directly from the chart, and if the chart is once thoroughly understood, the variations of these quantities can be visualized more readily than from a tabulation.

Load Factor.

(Refer to chart for West Penn schedule "J.")

Table 2 also serves to show the increase in cost and penalty as load factor decreases. This may be better shown on the chart, however, by assuming two customers with equal maximum demands, say 2,400 kva and different load factors. If one customer consumes an amount of energy equal to 600 hours' use of his demand, the load factor will be $600 \div 730 = 82$ per cent, and from the chart the cost is found to be \$14,700, or \$.0102 per kwh. If the second customer consumes an amount of energy equal to 300 hours' use of his demand, the load factor will be 41 per cent, and

*Since 1 month = 730 hours,

$$\text{Load factor} = \frac{\text{average power}}{\text{maximum power}} = \frac{\text{max. dem.} \times \frac{600}{730}}{\text{max. dem.}} = \frac{600}{730}$$

the cost is found to be \$9,800 or \$.0136 per kwh. Since $\$.0136 \div \$.0102 = 1.33$, it is evident that the latter consumer has been penalized 33 per cent for low load factor. As was explained previously, this higher rate is justified because the fixed charges on equipment installed for him are equal to those installed for the other customer, but are spread over a smaller block of energy, viz., 300 hours' use of the demand instead of 600 hours' use.

Minimum Charge.

The minimum charge for Duquesne schedule "F" is found by following the demand line, which represents 75 per cent of the connected load, back to the cost scale. For example, assume 2,400 kw connected load. $2,400 \times .75 = 1,800$ kw. The minimum charge is found to be about \$2,300.

The minimum charge for West Penn schedule "J" is established as the equivalent of 25 hours' use of the maximum demand at any time established, subject to certain qualifications as quoted in Article II. This cost cannot be determined from the chart for larger consumers, since this chart gives only the net costs, and term discounts are not applicable to minimum charges. The supplementary chart for small consumers, however, gives both gross and net costs, so the minimum charge can be determined as follows:

Suppose the maximum billing demand established for any billing month to be 2,000 kva. Twenty-five hours' use of this demand = $2,000 \times 25 = 50,000$ kwh. The gross cost of this quantity is determined by the intersection of the vertical line at 50,000 kwh with line "B." This is found to be \$3,000 gross. Although term discount is not applicable, the two per cent prompt payment discount may be deducted; hence the minimum charge is $\$3,000 - \$60 = \$2,940$ per month.

Power Factor.

(Refer to chart for Duquesne schedule "F.")

Since the power factor penalty charge is made by increasing the billing demand, the effect is similar to that shown in Table 1. Thus, the variation in the cost of 750,000 kwh at 3,000 kw metered demand is as follows:

(Note that the "permissible" power factor for 1,000 kw demand or over is 90 per cent.)

Power Factor	Billing Demand	Total Cost for Month	Penalty for Low Power Factor	Net Cost per kwh
100%	3,000	\$11,950	\$ 0.00	\$.0159
90	3,000	11,950	0.00	.0159
80	3,375	12,700	750.00	.0169
70	3,860	13,650	1,700.00	.0182
60	4,500	14,900	2,950.00	.0199

Off-Peak and Limited Service.

(Refer to chart for West Penn schedule "J.")

The chart shows clearly the reduced cost of off-peak service. Under this clause, the billing demand is taken as 25 per cent of the metered demand. If the example shown on the chart were under this clause, the billing demand would be $3,000 \text{ kva} \times .25 = 750 \text{ kva}$, and the cost would be about \$6,300, or \$.0096 per kwh. This is only 60 per cent of the cost under general service.

Limited service effects a similar, but smaller saving, as the billing demand is taken as 70 per cent of the metered demand.

Procedure to Reduce Power Costs.

After becoming familiar with the effects of the load conditions upon the cost as just explained, the thrifty engineer will scrutinize the type of electrical and mechanical equipment which is to be incorporated into his plant, selecting the kind, type, and size that will not only be efficient in performing its intended functions, but such that will have load characteristics conducive to low power costs, and if possible, such that will tend to correct for poor conditions in other parts of the system.

As to the existing equipment under his charge, he will apply his portable recording ammeter and power factor meter to the supply point, and determine the characteristic of his demand and the time of day that excessive demands occur. He will then obtain similar data from each individual or group of power consuming devices; and having listed the offenders in rank order as to the penalties which they impose, he will determine whether the savings obtained by replacing the equipment or installing corrective devices would justify the necessary expenditure.

In order to have before him an ideal or "goal" at which to "shoot," the engineer should make the following division of his power cost, and then observe from month to month how near he approaches the "bull's-eye."

Refer to the example indicated on the chart for Duquesne schedule "F." The cost shown is \$11,950. Now, if it were possible to reduce the penalties to zero, the billing demand would be 1,027 kw (load factor = 100 per cent) and the cost would be \$8,100, which indicates a saving of \$3,800 per month, or 32 per cent of the bill as rendered.

From the consumer's point of view, then, he is paying \$8,100 for power consumed, and \$3,800 for penalties.

Of course, it is impossible to reduce the penalties to zero, because ideal conditions cannot be obtained; but they can be approached by altering the conditions for which penalties are imposed.

Means of Reducing Penalties.

The conditions for which penalties are imposed have been thoroughly explained, and the methods of altering these conditions will be discussed in the same order.

It is assumed that the energy consumed per month has been reduced to a minimum, so the question of efficiency of the consuming devices is eliminated from this discussion. Efficiency is quite thoroughly understood by the engineers in charge of a plant, and great pains are taken to reduce the energy consumption to the least possible amount. Our problem, then, in reducing the monthly bill, is to obtain the lowest rate per kwh of energy consumed.

Load factor has been defined as the ratio:
$$\frac{\text{average power}}{\text{maximum power}}$$
 and it has been shown that the rate is reduced by increasing load factor, which means: by decreasing the denominator of this fraction, "maximum power," since the average power is fixed by the monthly consumption of energy. Load factor and maximum demand may, therefore, be considered together.

Maximum Demand and Load Factor.

Maximum demand occurs in periods of peak loads. The problem, then, is to shift some of the energy con-

sumed during period of peak demands to other periods of lesser demands.

The problem of storage of large quantities of energy has never been satisfactorily solved. Means are available, however, for the storage of sufficient quantities to materially reduce peak loads on most kinds of equipment. These may be classified as: chemical storage, kinetic storage, and potential storage.

The most common example of the storage of chemical energy is the storage battery. The high first cost and large amount of space required, practically eliminate their use for industrial power loads. Further, they cannot be used with alternating current. Their use is restricted then to small consumers who rectify the alternating current to direct current.

The common example of the storage of kinetic energy is the flywheel. By an increase of rotating speed, the flywheel is made to "absorb" a quantity of energy which is made available again when the rotating speed is decreased. It is evident that since the use of flywheels is dependent upon a variation of speed, they cannot be used in direct connection with synchronous motors, as these machines must operate exactly in step with the generator from which they are receiving power. Flywheels may be used with direct current machinery or with alternating current induction motors, and wheels weighing more than 100,000 pounds are sometimes used for this service in connection with mine hoists or steel rolling mills.

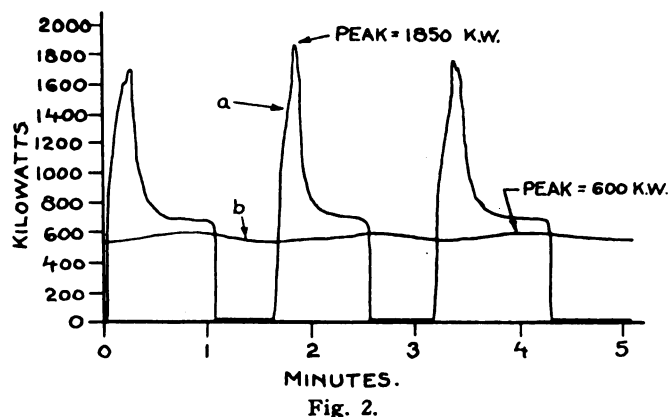


Fig. 2 shows graphically the reduction in maximum demand by the use of a flywheel set between the service line and a mine hoist motor. The kw line "a" shows the power delivered from the flywheel motor generator set to the hoist motor. If the hoist motor itself were receiving power directly from the central station under West Penn schedule "J," the maximum demand would be determined as follows:

The interval demand for the five-minute interval shown is 555 kw (obtained by means of a planimeter). This is assumed to be the maximum for the billing month. The maximum instantaneous demand is 1,850 kw. Since this is greater than 150 per cent of the maximum interval demand, one-half of the excess, or 509 kw is added to the maximum interval demand, and the billing demand is found to be $555 + 509 = 1,064$ kw. Assuming that the hoist operates at the rate indicated by the curve, 200 hours per month, the monthly consumption would be $555 \times 200 = 111,000$ kwh. The cost of power for the month is found from the chart to be \$3,150.

Actually, the flywheel set, irons out the peaks into a very smooth curve, as indicated by the line "b,"

which shows the power delivered from the central station to the flywheel motor generator. The maximum demand for this curve is 600 kw. Allowing 12 per cent for losses in the motor generator, the energy consumption would be $111,000 \div .88 = 126,000$ kwh. The cost of this energy is \$2,350, which indicates a saving of \$800 per month, or 25 per cent, made possible by the use of the flywheel.

Potential energy may be stored by accumulating a fluid under pressure or at an elevated position. Where air is compressed or where water is being pumped, this means of storing energy may be used to advantage, and the peak loads on the driving motors thus reduced. Practically every air compressor is installed with a receiver on the discharge line, but too often the receiver selected is too small for the service, or additional compressors are later installed without providing additional receiver capacity.

Water under load head can be accumulated in overhead open tanks or reservoirs, and sufficient capacity is easily provided, but water under high pressure (e. g., 2,500 pounds per square inch, which is commonly used for presses and draw benches) must be stored in a closed vessel under pressure. The type of accumulator in common use is clumsy and costly, and for this reason many are in use which are entirely too small for the service.

The size and rate of operation of pumps* used with accumulators is important. The ideal combination would be a pump and accumulator of such size that the pump could operate continuously at an average rate just sufficient to meet the hourly demand for water, the accumulator taking care of all irregularities. Since this ideal condition can seldom be obtained in practice, a compromise is reached by selecting an accumulator smaller than the ideal size and operating the pump or pumps at a higher rate than the hourly average demand. It is obvious that the pumps must be cut out and in, occasionally, in order to prevent overcharging the accumulator, and that the greater the number of "off-time" minutes there are in each hour, the harder the pumps must work during the time they are on. To reduce the peaks, then, the pumps should be run at as low a rate as possible without allowing the accumulator to become empty. If the pumps are operated by direct-connected synchronous motors, the speed is not adjustable, and if cutting out one pump entirely is too much of a reduction, the only recourse left is greater accumulator capacity.

Power Factor.

Low power factor is caused principally by transformers and induction motors, and the lower the percentage of rating at which these are operated, the lower the power factor will be. They should be selected with wisdom, since it is usually considered necessary to provide excess capacity for future extension or an increased rate of operation, which requires larger equipment, while the power factor consideration favors smaller equipment.

High-speed induction motors do not reduce power factor to so great an extent as low-speed motors, and this is one advantage which reducing-gear drives have over direct-connected drives for low-speed machinery.

*In this paragraph "pump" represents either pump or compressor, and "accumulator" represents either accumulator or air receiver.

Synchronous motors and synchronous converters, when provided with normal field excitation, operate at unity power factor. If the field is under excited or cut off entirely, they operate similar to induction motors and the power factor will be reduced, little or much, according to the degree of under-excitation. If the field is over-excited, the power factor of the motor will be somewhat reduced, but the excess line current, instead of increasing the loss, will counteract some of the excess line current from induction-motors and transformers and decrease the loss, so that the power factor of the system as a whole will be increased.

On account of the necessity of direct current for field excitation of synchronous motors, they are not used in small sizes, but for motor-generators where flywheels are not used, and for large power drives generally, synchronous motors can often be used to advantage, and considerable power factor correction can be obtained.

In systems where power factor correction is needed, and which do not contain synchronous motors, auxiliary equipment can be added for this purpose, in the nature of static or synchronous condensers. Static condensers are much to be preferred, inasmuch as there are no moving parts; hence the operating losses are low and an attendant is not required. But commercial sizes are limited in capacity and only small sizes are available.

A synchronous condenser is nothing more nor less than a synchronous motor which is "floated" on the line and operated without load. By over-exciting the field to the proper extent, a current is generated in the line which counteracts the excess current in the system, so that unity power factor prevails at the service connection and back on the feeder until the load combines with another consumer's load with different power factor. If excess condenser capacity is provided, low power factor, due to other customers, will be partially corrected for. The West Penn schedule provides a special discount under "Line Regulation Discounts" (cf. Article II) to encourage the use of such apparatus.

Example of Reduced Penalties.

In order to show how the foregoing factors work out in practice, a hypothetical case is represented by Table 3.

The energy consumption and load factors are arbitrarily assumed, and the maximum demands are calculated therefrom. The billing demand is obtained from the sum of the individual maximum demands by applying an assumed diversity factor of 1.25. This means that the ratio of the sum of the individual maximum demands to the maximum demand of the whole system is 1.25, or that the maximum demand of the system is $\frac{1}{1.25} = .80$ or 80 per cent of the sum of

the individual maximum demands. That the assumed initial conditions are not below the average is indicated by the fact that the load factor of the system, as based upon the billing demand, is 30 per cent, while the average load factor for twenty representative customers under this schedule which were examined by the author, was well under this figure. Also that the improved load factor, 45 per cent, is not impossible, is indicated by the fact that of the twenty cases examined, four have load factors above 45 per cent, and one is better than 64 per cent.

Table 3.
Typical Comparison of Initial and Improved Conditions.
(Based upon West Penn Schedule "J")

	Initial Conditions			Improved Conditions			Reference Notes
	Kwh Consumed per Month	Monthly Load Factor	Kva Max. Demand	Kwh Consumed per Month	Monthly Load Factor	Kva Max. Demand	
Air compressors	120,000	.24	685	120,000	.48	342	(a)
Hydraulic pumps (high head)	80,000	.16	685	80,000	.32	342	(b)
Hydraulic pumps (low head), centrifugal, for general service)	57,000	.40	195	57,000	.45	183	(c)
Motor generator sets (general plant service)	400,000	.25	2,185	400,000	.34	1,610	(d)
Totals	657,000	...	3,750	657,000	...	2,477	
Billing demand, or composite maximum demand (diversity factor assumed 1.25)	...	...	3,000	...	...	1,980	
Composite monthly load factor (based upon billing demand)	...	.30	...	...	.45	...	
Net cost of power	(Initial) \$10,490			(Improved) \$8,590			
Net saving per month				\$1,900			

Reference Notes.

a. Graphic ammeter showed that four compressors in operation were all "on" 33 per cent of the time and all idle 67 per cent of the time, swinging on and off at short intervals. By installing additional receiver capacity and re-arranging control device so as to cut off one unit at a time, it is found that two units would carry the entire load, one operating "on" 90 per cent of the time and the other one "on" 42 per cent of the time, dropping out of operation during periods of low demand for air.

b. Conditions similar to (a). Load factor doubled by installing larger accumulator and arranging control so as to cut off one unit at a time.

c. Induction motor drive. Graphic ammeter record shows that starting current is greater than normal operating current. By having the connections changed in starting compensator, the starting current may be reduced.

d. Graphic ammeter indicates that maximum demand occurs at 1:00 P. M. and corresponding hours when machine operators start a large number of motor-driven machines simultaneously and carelessly. Starting demand reduced by "staggering" (i. e., by starting the motors in groups at intervals of say one minute) and by re-arranging the resistance taps of large motors equipped with automatic starters, so that a lower starting current is drawn from the line.

The power factor penalty was not considered in the example as tabulated, since the motor generator sets, and likewise the pumps and compressors, might have been driven by synchronous motors at 100 per cent power factor. Assuming, however, that induction motors operating at an average of 70 per cent power factor were used, the billing demand for the initial conditions would have been

$$3,000 \times \frac{100}{70} = 4,290 \text{ kva}$$

and the bill would have been \$12,900. Now, if a synchronous condenser be provided so as to obtain 100 per cent power factor, the new bill would be \$8,590, as shown in the table. The total saving now becomes \$12,900 -- \$8,590 = \$4,310 per month. Further, if the synchronous condenser installed had sufficient capacity to obtain 90 per cent leading power factor or better at the customer's service connection, so as to earn line regulation discount, he would be billed for 657,000 × .95 = 624,150 kwh. The cost of this

quantity of energy at 1,980 kva demand is \$8,350, and the total saving then becomes \$12,900 -- \$8,350 = \$4,550 per month, or \$54,600 per year.

The annual saving indicated would undoubtedly pay for the new receiver, accumulator, and condenser in about one year, and would pay a 100 per cent dividend on the investment thereafter. This is a better investment than any stocks or bonds on the market.

In conclusion, it is pointed out that the pursuit of economy should not stop with the highest obtainable thermal and mechanical efficiency. The exact analysis outlined in this article does not fit all cases, but the principles do apply to every consumer of purchased power under these and similar schedules; and to obtain the maximum saving, each system must be thoroughly analyzed by considering all the existing conditions.

MANY MEN NOT WORKING

Unemployment is still increasing in iron and steel works, according to the Bureau of Labor Statistics report for July, which shows a loss of 14,633 men from June, representing 12.7 per cent. The loss from July, 1920, is 89,000 men, or 46.9 per cent. Payrolls showed an even greater decrease, the drop from June to July being 24.4 per cent, while that for the year was 71.4 per cent. As a result, the individual pay envelope has fallen from \$72.11 in July, 1920, to \$38.17 last month—a cut of 47.1 per cent. This decrease in earnings is greater than the 43.5 per cent drop in the cost of living, from July, 1920, to July, 1921.

Comparative figures for June and July, 1921, and July, 1920, in iron and steel mills, automobile factories and car building and repairing shops follow:

Month	Number of—		Half-Month Payroll	Average Pay Envelope
	Establishments	Men		
Iron and Steel—				
June, 1921 ...	118	115,411	\$5,088,831	\$44.10
July, 1921 ...	118	100,778	3,846,541	38.17
July, 1920 ...	118	189,770	13,683,927	72.11
Automobiles—				
June, 1921 ...	45	76,734	2,620,084*	34.15
July, 1921 ...	45	79,064	2,622,596*	33.17
July, 1920 ...	49	126,997	4,335,639*	34.14
Car Building and Repairing—				
June, 1921 ...	59	39,335	2,670,021	67.88
July, 1921 ...	59	38,378	2,272,954	59.23
July, 1920 ...	62	65,386	4,082,301	62.43

*Weekly.

Steel Foundry Makes Sugar Mill Machinery

Very Interesting Discussion on This Machining and Engineering Work—Roll Shells—Their Materials and Its Making.

By JAMES J. ZIMMERMAN,
Assistant Superintendent, Scott Foundry,
Reading Iron Company.

PART I.

It is not the writer's intention to present to our readers a series of articles dealing with the engineering and metallurgical facts, theories or principles underlying the successful and economical manufacture of sugar plant equipment, but rather his object is to confine his writing to the milling or rolling end of the industry, and to logically give data and information which may suggest to, or aid, the purchaser of such equipment to choose and choose wisely. At the same time he hopes to familiarize interested readers with this class of machine and engineering work.

Roll Shells—Their Material and Its Making.

Fundamentally, the basis of all successful milling plants is the rolls, hence roll shells, their material and making, are first discussed. There are three distinct materials for roll shells, viz.:

1. Cupola iron
2. Charcoal gun iron
3. Steel

Cupola iron roll shells are made from iron which in turn is made in a cupola, which is simply a shaft furnace. This consists of a vertical cylinder of steel plates lined with fire brick, with the top open to receive the alternate charges, in layers, of fuel and metal. At the bottom a blast is introduced, and the metal and slag withdrawn. In a cupola, the production of iron in tons per hour is dependent upon the inside diameter of the cupola, and the amount and velocity of the blast. A general idea of these ratios follow:

Inside Diameter of Lining in Inches 36" to 90"	Tons Per Hour Melted 4½ to 30	Cubic Feet Blast Per Second 37½ to 250	Velocity of Blast Feet Per Second 5.33 to 5.66
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Unfortunately the metal in a cupola can not be worked, and the grade of iron which is tapped out is dependent entirely on the calculated charge. This method of charging fuel and metal of certain analysis into the cupola, estimating the actions or reactions, and the losses, trusting to tap out a finished iron to a required analysis, or to change it by additions in the ladle, is very undependable. This practice is reliable enough for some castings, where limits are permitted, but not so for rolls requiring a definite composition determined by experience as necessary to produce certain results.

An air furnace of the type as is found in modern gray iron foundries is a hearth furnace whose fire box

and melting chamber are separate. The draft, which is dependent on the chimney height, draws the flame from the coal fire over the bridge wall and on to the hearth, partially melting the charge and heating the walls and roof to incandescence, from which the heat is returned to the charge by radiation. It is this radiation from these surfaces which does the real work of heating and again superheating the metal.

Design of air furnaces varies according to the foundry as to the height of roof, area of fire box and hearth, location of tapping hole, charging doors, etc. They vary in capacity up to and beyond 20 tons. It can readily be seen that with this type of furnace a heat may be worked and additions can be made within the furnace, in order to obtain a definite composition prior to tapping, as is required for rolls. The average heat in an air furnace, say of 12 tons' capacity, is about six hours.

Air Furnace Charcoal Gun Iron vs. Ordinary or Special Cupola Iron.

Advantages of air furnace charcoal gun iron over ordinary or special cupola iron from a purchaser's viewpoint:

1. A higher priced iron of better quality, as will be pointed out below, due to higher priced and more skillful labor and maintenance costs, than are required in cupola.
2. Greater physical strength, as follows:

	Tensile Strength	Elastic Limit	Modulus of Elasticity
Cupola iron	22,066	6,500	13,194,233
Air furnace charcoal gun iron	30,500	11,000	16,130,300
Above from (G. Lauza Trans. A. S. of M. E. x 187.)			

Thomas D. West in his *Metallurgy of Cast Iron*, page 299, gives the following table, stating that the first analysis is from charcoal pig iron melted in an air furnace and that the second and third analyses are from a cupola and not charcoal iron.

No. of Analysis	Specialty Mixture	*Tensile Strength Per Square Inch	Tensile Strength Per Square Inch
A	Charcoal A. F. gun iron rolls, etc.	3,686	37,110
B	Heavy cupola castings	2,791	25,799
C	Light cupola castings	2,115	20,655

Mr. West states that in analysis "A" the combined carbon being so high with low sulphur and silicon not far from 1.00 per cent, gives an iron far superior

*From summary of 100 tests bar 1¼ inch diameter x 12 inches between supports.

No. of Analysis	Specialty Mixture	Sil.	Sul.	Phos.	Mang.	Graph. Carbon	Combined Carbon	Total Carbon
A	Charcoal A. F. gun iron rolls, etc.	1.19	.055	.408	.420	2.050	1.130	3.180
B	Heavy cupola castings	1.05	.110	.543	.350	2.650	.330	2.980
C	Light cupola castings	1.83	.078	.504	.310	2.500	.430	2.930

to any cupola iron. He attributes this gain in quality to the fuel and metal not coming into direct contact.

Mr. West states that in a cupola this combination may be closely approximated, but the working of the cupola, on account of the iron coming in contact with the fuel and blast, makes it a difficult and a very unreliable method to adopt.

3. Fuel and metal not in direct touch, hence absorption of sulphur from fuel less than in cupola. Sulphur in any proportion increases hardness, hence smoothness of the rolls and slipping during operation. It also increases shrinkages, hence internal strains and consequently breakage. It also unites with the combined carbon and produces hardness and brittleness to abnormal degree. This element is the most dangerous and detrimental in iron, and it is practically impossible to reduce it in any furnace. It is sometimes reduced by roasting the ore prior to its going through the blast furnace, where it is made into pigs for foundry use. In an air furnace the absorption is negligible, while in a cupola the iron, due to its contact with the coke, absorbs from 0.02 to 0.03 per cent from the coke. Logically the only way around the sulphur situation for roll practice is to begin with low sulphur or charcoal iron and work it under such process which does not increase this evil element, hence the air furnace.

4. Due to the same reason as in paragraph 3, oxidation is considerably lower, which consequently gives a better iron. Oxygen in iron raises the freezing temperature (or setting temperature) which shortens the life while pouring, hence little or no feeding can be obtained from risers or gates while cooling, hence voids and interior shrinkages. Such castings are unreliable and dangerous. Oxygen also has a tendency to increase combined carbon to a point where it destroys graphitic carbon, which gives the mottled texture, absolutely necessary for sugar mill rolls. Again it is a producer of gas, and, as Moldenke states, the reaction of the oxygen with the carbon forms carbon-monoxide gas. This actually goes on in the mold while the roll is being poured, as the cutting away of the skin of the casting, especially on the cope side. This is readily shown in the case of an oxidized iron and produces a beautiful collection of pin holes and gas pockets in the iron.

5. In air furnaces low silicon irons are used which are especially liable to oxidation, hence since silicon plays such an important part in the effect of the carbons which produce the combinations desired, it is easily seen that the air furnace again gains a point by the fuel not coming in contact with the metal. Silicon is a hardening element in cast iron, but on account of its influence on carbon it is usually considered a softener. During cooling it retards the combined carbon formation and increases the formation of graphitic carbon, which produces the mottled iron structure necessary in rolls. All of the above argues for control of the bath, as is possible in the air furnace, but not so in the cupola. Extremely low silicon produces a white fracture, while high silicon a gray, or beginning with hard white iron it passes on to a mottled iron, then to the soft gray iron, which is wonderful for machining but extremely low in strength.

6. The refining action of an air furnace, not obtainable in a cupola, with a flame almost reducing in character, prompts its use to the exclusion of other and cheaper means. The temperature of the furnace,

about 2,400 to 2,600 degrees F., is not sufficient to melt steel, hence there is absolutely small chance for burning or oxidation of the metal. When the metal is melted it is protected from further action by a silicious slag until tapped and poured.

7. Since air furnace gun iron rolls are made from cold blast charcoal iron pig, they again claim superiority over ordinary or special cupola mixtures, for they not only obtain all of the advantages of the air furnace over the cupola as enumerated above, but also derive the following from the metal itself.

a. Because its tensile strength is greater, which runs according to grade used from 35,000 to 42,000 pounds per square inch.

b. Because the structure is finer and closer grained.

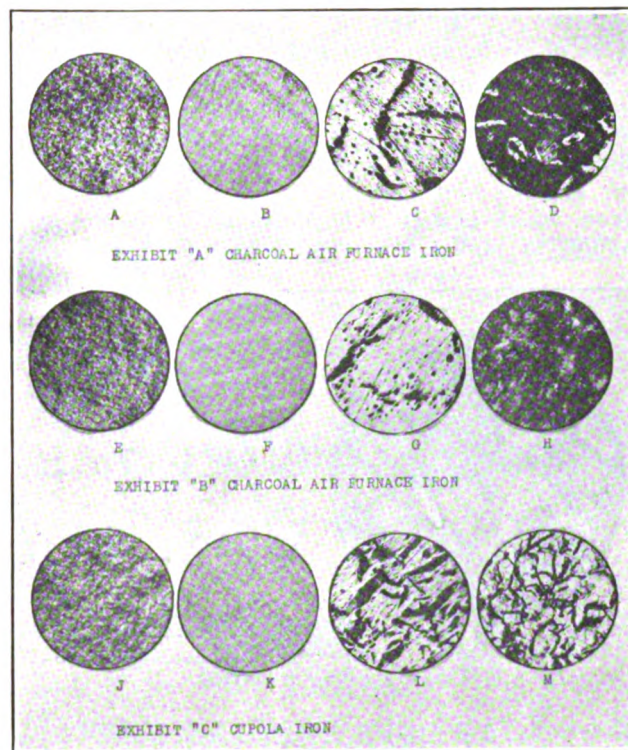


Fig. 1.

c. Because of the low sulphur and phosphorus.

d. Because the definite and straight cleavage planes of graphite, so pronounced in coke pig irons, are missing, the metal naturally is more firm, closer grained and stronger.

e. Let charcoal iron be melted in a cupola, and its contact with the coke will soon bring the superior qualities of it down to a level with coke or anthracite iron. Hence, to maintain its good properties the air furnace must be adhered to.

f. Production of cold blast charcoal iron is from 6 to 8 tons per day, and requires about 150 bushels of charcoal per ton of pig. Warm blast charcoal iron is from 15 to 25 tons per day. Coke and anthracite pig iron production runs into hundreds of tons per day.

8. At this point we quote Dr. Richard Moldenke, from his Principles of Iron Founding, page 435: "Many foundry men hold that they can do just as good work with a cupola as the air furnace, and, indeed, many castings are made today from furnace iron which could just as well come from the cupola. The fact

remains, however, that an air furnace roll is ahead of one made from the cupola for certain mill uses, and there is no getting round the situation."

9. Experience has shown that charcoal gun iron, which is hard enough to withstand strains and shocks, yet soft enough not to wear smooth, open grained enough to prevent slippage, yet close grained enough to prevent excessive corrosion caused by action of weather and juice, gives a longer life and consequently a cheaper roll for all sugar mill work. Reading Iron Company is prepared to guarantee their rolls of air furnace gun iron, with charcoal pig as a base, to give 30 per cent more service than those made from cupola iron.

In order to further bring out the difference between air furnace iron and cupola iron, and to show the superiority of the former, I am referring you to Exhibits "A," "B" and "C," showing respectively two grades of air furnace iron and one of cupola iron.

This is a highly refined product of the air furnace, known as gun iron, with high tensile strength of 31,000 pounds and other physical properties as set down in a former tabulation. It is low in phosphorus and sulphur, and has in it a small amount of manganese. The silicon, which is neither high nor low, is of the proper amount to sufficiently retard the combined carbon

specimen of high grade strong air furnace iron, also known as gun iron. Like the iron of Exhibit "A," it is also made with cold blast charcoal iron for its base. This iron is closer grained and consequently stronger than the former specimen.

Photo "E" shows the fracture and the close grain, making a strong and enduring iron of 37,000 pounds tensile strength, with other physical properties in proportion, wonderful for castings under heavy strains, such as housings, bed plates or rolls for steel or iron rolling, but unsuitable for sugar mill rolls. Photo "F" shows this piece of iron machined, and bears out the statements about photo "E."

Photo "G" is an unetched micrograph of 100 diameters taken off the same piece of iron. It shows at a glance that the structure is similar to that of the iron in Exhibit "A," but in addition shows a less amount of graphitic carbon, and more combined, hence greater strength and hardness. A study of the etched micrograph "H," of the same diameter and of the same piece of iron, further bears out this statement.

The specimen shown under this exhibit is of an exceptionally high grade cupola iron of 23,000 pounds tensile strength, not made from charcoal pig iron. It is somewhat higher in sulphur and phosphorus, and very much higher in silicon, than the specimens of Exhibits "A" and "B," and consequently the combined carbon is lower and the graphitic carbon higher, which in lieu of the effects of the differences in the proportions of the other elements, would naturally result in a less tough and weaker quality of iron. This will all be noted by a comparison of the unetched and etched micrographs "L" and "M," respectively, of 100 diameters each from this specimen with those of the irons of Exhibits "A" and "B." Particular attention is called to the increase of graphitic carbon, shown in micrograph "L," which forms in a greater number of plates than in the samples of air furnace iron, which results in the formation of straight and definite cleavage planes, which reduces the firmness and strength of the iron. This specimen of cupola iron shows no comparison of the actual and full sized photographs "J" and "K" of its fracture and machined surface, respectively, with similar photos of the air furnace iron, lead one to believe it an iron equal in strength, toughness and wearing qualities, had been produced. The micrographs soon contradict this assumption, and the analysis would strengthen the contradiction, while the physical tests would show a weaker and inferior iron.

Steel.

Steel, as it is spoken of today, embraces a multitude of mixtures, similar in structure yet vastly different in both chemical and physical qualities. Carbon is the element in steel which exerts the most influence upon its quality. Pig or cast iron contains up to about four per cent of this element; wrought iron only a trace; while steel lies between the two extremes, and its manufacture, therefore, refers principally to obtaining the proper proportion of carbon. One method of making steel is to burn out the carbon from the pig iron, as in either the Bessemer, open-hearth or electric furnace processes, and the other method is to take wrought iron and add carbon to it, as is done in the cementation or crucible process. Details and differences between these processes may be studied in almost any reliable text book.

In writing of steel, as pertains to rolls, we write strictly of steel castings, and, further, to crusher rolls

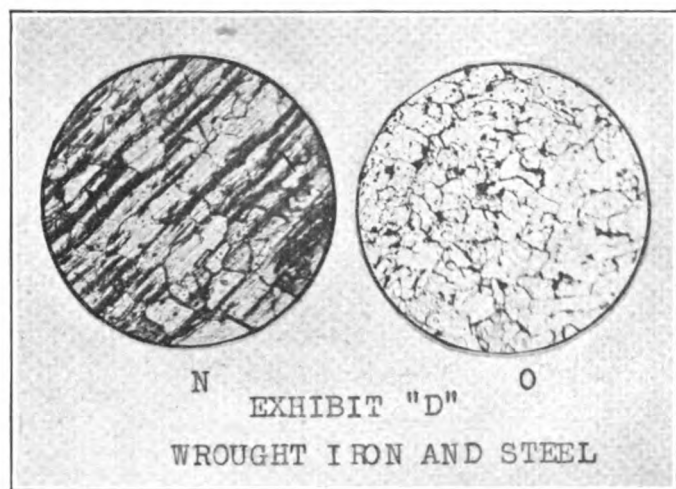


Fig. 2.

while cooling, and to change the proper proportion of same to graphitic carbon, in order to obtain the mottled structure or open grained iron necessary for sugar mill rolls. Primarily this iron was made from cold blast charcoal pig iron, and it is especially from this base that the iron obtains its excellent qualities.

Photo "A" is an actual and full sized photograph of a fracture. The mottled or star-like structure produces the open grain so desirable. This is corroborated by Photo "B," which is of the same piece after machining.

Photo "C" shows an unetched micrograph of 100 diameters of the same piece of iron. Note the proper proportions of the carbons. The graphitic sufficiently prominent to insure above stated requirements, yet not in definite cleavage planes which tend to weaken the structure. At the same time the combined carbon is shown in great enough proportion to still maintain the high strength. This is corroborated by the etched micrographic photo "D" of the same diameter and of the same piece of iron.

These photos of this second exhibit show another

only. Steel castings, such as crusher rolls, are almost universally made from open-hearth steel by the acid process, although many foundries are now securing satisfactory results from basic furnaces. The superiority of the acid process over the basic is a point of much contention, and the writer feels that he can but adhere to custom in claiming preference for the acid process steel, principally for the following reasons:

1. Because in the melting process of an acid furnace, the melter has no control over phosphorus and sulphur, the most destructive elements in steel, while in the basic both elements can be appreciatively reduced. Hence a purer and better grade of material must be used, and the chances are that a better quality of finished steel will be obtained.

2. Because of the greater possibilities of higher oxidization in the basic furnace than in the acid. The principal effect of oxygen is a wild or unsettled steel, which naturally will, if poured, have an effect on the segregation or cooling of the casting. It gives to the steel a shorter life, hence voids, blow holes and abnormal shrinkages.

3. Because more is known of making steel castings by the acid process than the basic, due, of course, to longer experience, hence we feel that the acid process is beyond the experimental stage and that the results required can be readily and surely obtained.

The essential requisites of steel for castings follow:

1. That it must be low in sulphur and phosphorus, which cause red shortness, cold shortness, porousness, weakness, extreme brittleness or general unsoundness of quality.

2. That it must be dead melted and free from over-oxidization or tendency to wildness.

3. That it must be hot and very fluid, in order that it may run well into the moulds.

Due primarily to the relatively large shrinkage of steel ($3/16$ inch per foot), large internal strains are set up and in order to relieve these stresses and to replace the original crystalline structure by a finer and more uniform one, steel castings are usually annealed, by bringing them up gradually and uniformly to a temperature of 800 to 900 degrees C., depending upon the composition of the steel, and allowing them to cool.

Since I have stated that steel castings, as pertains to sugar mill rolls, refer only to crusher rolls I want to add, however, that many crusher rolls are made from high-grade air furnace iron, such as heretofore described, and they perform very excellent service. A comparison, however, of the strength of steel with air furnace iron will at once show the average reader that for crusher duty steel is much preferable. Kerkaldy's tests published in the American Machinist, May, 1893, give for steel castings, from 44 tests, an average tensile strength of from 54,928 to 63,840 pounds per square inch. The main point is that the crusher rolls perform a more severe duty than the grinding rolls, and naturally should be stronger. Again this duty of crushing the cane, in addition to being more severe than grinding same, is more or less irregular and naturally subject to more shocks.

Although this company will make crusher rolls of air furnace iron, but positively not of cupola, and guarantee them, they feel that from experience they must recommend steel. It is, therefore, the policy of this company to furnish steel cast crusher rolls of from .40 to .60 carbon for all installations.

Shafts—Their Material and Its Making.

So far we have written only of the material for grinding and crusher roll shells, and insofar as these shells must have shafts in them, the writer feels that the material for these shafts should receive some discussion.

There are two classes of material from which shafts are made, namely:

1. Wrought iron
2. Forged steel

In the manufacture of wrought iron, the pig iron is remelted in a puddling furnace by charging about a half ton of metal, and while it is in a molten state it is stirred with a large hook by the operator, or puddler, and kept boiling so as to expose every part of the iron bath to the action of the flame, in order that the carbon may be burned out. The other impurities in the pig will, during the puddling, separate from the iron and form the cinder.

Now pig iron melts at about 2,100 degrees F. and wrought iron at about 2,800, and due to the temperature in the puddling furnace being low enough to melt

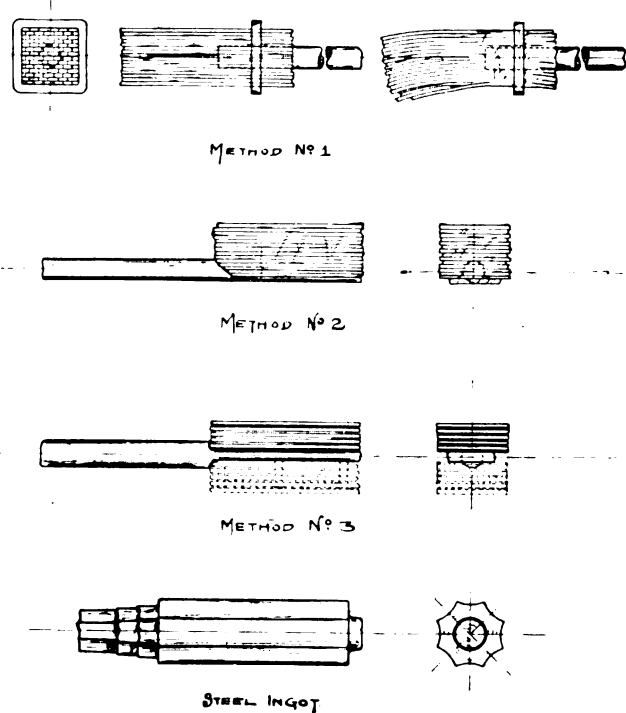


Fig. 3.

the pig, but not high enough to maintain the wrought iron in a liquid state, the small particles of iron purify and partly congeal (come to nature). Thus they form a spongy mass in which small particles or globules of iron are in a semi-plastic state, which adhere to the fluid cinder which fills the cavities between them. This mass is taken from the furnace and either hammered or squeezed, in order to expel the cinder. While still hot this mass, as it comes from the squeezer, is rolled into flat bars called muck bars. This process of hammering, or squeezing, and rolling the bar back and forth, elongates the globules, and gives the iron a fibrous structure, and the more rolling or hammering which is applied to the iron, the closer grained it becomes, consequently giving it greater strength and ductility.

Fundamentally all steel is cast, if not into special castings, then into ingot moulds, and the ingots are either rolled or forged into required shapes or sizes. Steel, like iron, becomes closer grained and stronger with repeated hammering or rolling. Since I have already discussed steel casting, I shall not again go into the manufacture of it, and will simply compare the relative merits of wrought iron forged shafts with those of steel.

Wrought Iron Shafts vs. Steel.

While both steel and wrought iron are chemically very much alike, they are vastly different when compared physically. Owing to the globules of pure iron being coated with cinder which is partially expelled by working, as before explained, wrought iron has a fibrous structure, while steel which is produced, as before noted, in a liquid form where the cinder or slag all floats on the top and is removed before pouring, is a metal homogeneous in nature, or in other words, without fibre. This difference in structure may be seen by examination of Exhibit "D," Fig. 2, which shows micrographs of wrought iron and steel of 100 diameters. "N" shows the fibrous structure of wrought iron, and "O" the non-fibrous structure of steel.

When subject to vibrations or strain, torsional, bending, or otherwise, wrought iron will generally yield gradually and give warning, while steel will usually snap or break off suddenly. Wrought iron being composed of fibres, the fibres can break off one at a time without directly affecting its neighbor (like strands in a cable or rope), while any rupture in steel will extend very rapidly if not cause instant fracture.

It would be useless to argue that wrought iron has a greater strength than steel, for such would not be true, as the following figures will show, which have been set down by the United States Government as the physical requirements for heavy forgings or shafts. All tests to be made from test pieces taken from a two-inch bar.

	Wrought Iron	Steel
Minimum tensile strength....	50,000	60,000 to 80,000
Minimum per cent elongation.	22	35 to 25

Reading Iron Company, whose wrought iron shafts are figured, according to their duty, with a high enough factor of safety to cover the lower strength, strongly recommends wrought iron, due to its structure, in preference to steel, claiming that the slight difference in costs more than warrants its selection. Reading also forges steel shafts and guarantees every shaft which leaves its plant.

In line with the above, let me state that the writer knows of a number of engine flywheel shafts which repeatedly failed when made from steel, causing much damage. These were replaced by wrought iron and are, and have been for a number of years, still in service. I am also advised that the older sea captains argue for wrought iron propeller tail and line shafts for their vessels, claiming them more reliable and better as before stated. I am further advised that vessels have been known to cross the Atlantic no less than six times with a cracked wrought iron tail shaft before replacement was made necessary by fracture. Such evidence should warrant the choosing of wrought iron for all sugar mill roll or gearing shafts.

Wrought iron, as I believe I have convinced you, is superior for shafts, yet wrought iron will fail. Most of the failures are due, however, to improper manufacture caused by an unscrupulous desire of the maker to increase profits at the expense of an inferior product.

Remember the quality of forged wrought shafts depends entirely upon the method used in making up the pile or bloom, and the successful welding of the bars or sheets, from which it is built up into one solid mass. Note in the fagot method (1) that bars are piled together surrounding the porter bar and that they are held together at only one point by a square band. In this manner the pile is placed in a heating furnace, where it is heated for forging and where it is hoped that the pile will become sufficiently heated to permit welding. In this method the outside bars become heated and partially weld, but due to the distance to the center the inner bars in many instances are not welded when placed under the hammer. As a matter of fact, the Superintendent of the Reading Iron Company's forge states that in the majority of forgings made in this manner, failure is inevitable, and that the only excuse for employing such method is the desire to cut costs. On the right, illustration shows how the pile looks when drawn from the furnace, and note the lower layers or bars have drooped and torn themselves from the pile even before reaching the hammer.

Method (2) consists of building a pile of sheets or slabs directly upon each other, and placing them in the furnace for heating and partial welding. Similar to method (1), the welding of the inside of the pile is dependent on the conduction of the heat through the successive plates from the outside. As previously stated for method (1), this second method of piling is unreliable and the chances of the pile being properly welded in the interior are slim.

Method (3) insures a perfectly welded pile, due to thin strips being placed in the middle and ends of the pile and between the slabs, of which it is made up, thus permitting the heat to pass through and bring all parts to a temperature sufficiently high to positively insure welding under the hammer. The pile is built up first as shown by full lines heated and welded under the hammer, then it is built up on the opposite side of the porter bar and welded as before and forged to the desired shape.

A sketch of a steel ingot is shown, and it is from ingots of this shape, which some times weigh many tons, that sugar mill roll and gearing shafts are forged, simply by heating prior to placing under the hammer or forging press. Please bear in mind that even though forging creates a closer grained and denser steel, it can not and does not eliminate piping or other defects which usually are found in the center. These defects, which are usually found to be the cause of failure, are seldom discovered before the shafts are placed in service. It is, therefore, suggested that all orders for shafts should specify hollow bored. This policy has been adopted by the majority of railroads, for it permits the discovery of defects in the center of the forgings prior to their acceptance and actual service.

(To be continued)

ERROR IN GORDON FOX'S ARTICLE

In the article "Electric Motor Drives for Traveling Cranes" published in the August issue of THE BLAST FURNACE AND STEEL PLANT magazine, errors occurred in the first two formulas on page 485. The first formula should be

$$DB = (D_r + D_a) \frac{W}{2000}$$

and the second formula should be

$$T_r = \frac{D_r}{D_r + D_a} \times 150$$

Effect of Overheating High Carbon Steel

Overheating Produces Many Undesirable Characteristics — The Greater Hardening Power of Oil and the Deeper Hardening Power of Water When Steel Is Overheated Are Explained.

By LANCELOT W. WILD, M.I.E.E.,
Automatic and Electric Furnaces, Ltd., London.

TO obtain complete surface hardening of a high carbon steel, the material must be heated until it becomes completely non-magnetic, and it must then be quenched.

If, instead, the heating is stopped at the end of the decalescence period, the steel will be only partially hardened. If, on the other hand, it is heated some way above the point at which the last trace of magnetism disappears, it will, although apparently fully hard by the file test, fail to stand up to its work.

Overheating produces the following undesirable characteristics:

A reduction of tensile strength.

A reduction of stiffness.

A reduced limit of elastic deformation.

A reduced impact test.

Reduced resistance to wear.

Reduced cutting power.

All this is well known, and is never now questioned by competent authorities.

Over-heating also produces another change, which has given rise to a good deal of controversy. Over-heating, followed by water quenching, increases the depth of hardening, and over-heating followed by oil quenching, increases the surface hardness. In other words, by over-heating, the same degree of hardness can be obtained with oil quenching as would be obtained with normal heating followed by water quenching.

It is sometimes said that over-heating, followed by oil quenching, is preferable to normal heating followed by water quenching, as less strain is produced. This is a complete fallacy. If the surface of the steel is to be glass hard, martensite must be produced. Martensite has a lower density than troostite; hence, it is impossible to produce it without strain. It is not the means but the end that produces the strain. Over-heating, on the other hand, weakens the steel and makes it less capable of withstanding the strain produced by the hardening operation.

The greater hardening power of oil and the deeper hardening power of water when the steel is over-heated is capable of explanation in three different ways.

Theory No. 1.

Le Chatelier has shown that when steel is quenched the temperature does not immediately start to fall at its maximum rate. It has been argued that when steel is normally heated, the rate of cooling has not yet attained its full value when the steel has cooled down to its critical temperature of transformation, so that the transformation is not always entirely suppressed.

If, however, the steel is overheated, the maximum rate of cooling is reached before the steel has cooled down to the transformation temperature, hence quicker cooling is obtained at the moment when it is most wanted. This is put forward in spite of the fact that Le Chatelier's curves show that the maximum rate of cooling is always reached with normal heating by the time the steel has fallen to the transformation point.

Theory No. 2.

When steel is heated to the magnetic change point, the cementite existing between the grains or crystals remains after quenching intact. When the steel is, however, sufficiently overheated this boundary ce-

mentite enters into solution and remains in solution after quenching.

The more cementite entering into solution the more it is likely to be retained on quenching, if the rate of cooling is not quite sufficient to retain the whole. Thus sufficient may be retained after overheating and quenching to produce great depth of hardening with water quenching, or complete surface hardening with oil quenching.

The writer favored this theory until experimental research proved it to be untenable.

Theory No. 3.

Overheating causes grain growth. Larger grains mean fewer boundaries for the heat flow to cross. From this one may infer that a higher heat conductivity would be obtained, and hence quicker rate of cooling. Thus, a piece of over-heated steel should cool more quickly than a normally heated piece of the same steel when quenched in the same liquid.

This theory appears to stand the test of experimental proof.

SUMMARY

Heating steel to the completion of the magnetic change before quenching gives the strongest, toughest, best wearing and best cutting steel.

Over-heating gives increased hardness for oil quenching and greater depth of hardness for water quenching, but this is obtained at the expense of all those qualities most desired in hardened steel.

Over-heating steel increases the size of the grains, thereby increasing the thermal conductivity and reducing the cohesion; hence the deeper hardening power and reduced strength.

Large masses can be hardened as perfectly as small masses by heating to the point when the steel becomes entirely non-magnetic.

Steel that has once been overheated can only be fully restored to its best condition by being re-forged. A triple heat treatment can, however, be employed which will go a long way to improve its condition.

Experimental Proof.

For the experiments a sample of steel was chosen with a carbon content of a 1.2 pc and a manganese content of .2 pc. A bar of half an inch diameter normally treated was known to harden to a depth of about 1/16 of an inch only.

Three pieces of this steel were prepared and were treated as follows:

A. Annealed from magnetic change point. Re-heated to just over magnetic change point and quenched in water.

B. Heated to 900 and quenched in water. Thoroughly annealed from magnetic change point. Re-heated to just over magnetic change point and quenched in water.

C. Heated to 1,000 and cooled down in furnace. Re-heated to just beyond magnetic change point and quenched.

Under the microscope A and B showed martensitic structure on the surface and troostite in the center. C showed martensite throughout.

A showed a fine grain with good cementite network. B showed a still finer grain with cementite in the form of dust and short filaments. C showed a very coarse grain, with very complete cementite network.

On fracture A and B showed a very fine grain near the surface, and a larger grain in the interior, while C showed a very coarse and uniform grain throughout.

On impact test A proved to be the best, C being extremely brittle. On bending test the specimens came out in the same order, C being very deficient in stiffness.

C was the only specimen that hardened to the center. The heating for the final hardening was the same for all, so theory No. 1 is completely disproved.

C had its full complement of undissolved cementite and yet hardened to the center. Therefore, theory No. 2 goes by the board.

Theory No. 3 stands unconvicted, and, if nothing more could be said, would hold the field as the sole survivor. Its position can, however, be further substantiated.

Two pieces of steel were prepared, the one given treatment A and the other treatment C. A rather rough and ready comparison of thermal conductivity was made, and it was found that C had a conductivity from 30 to 40 per cent greater than A.

It appears from these experiments that deep water hardening and complete surface oil hardening can only be obtained at the expense of grain growth, which means weak steel and, generally, a very unsatisfactory product.

Incidentally emerges the fact that when steel has once been over-heated no reasonable heat treatment can completely restore to it its virtue, but if it must be used, the best thing to do with it is to quench at once, re-anneal as thoroughly as can be afforded, and then re-harden normally.

The Heat Treatment of Large Masses.

It is sometimes stated that large masses must be over-heated, as otherwise they cool so slowly that good

hardening cannot be obtained. This is a fallacy, at any rate within the writer's experience, which extends up to masses of 40 pounds in weight.

If a laboratory test is made of a small specimen, and from the decalcescence point thus obtained a routine is set to the hardening shop, two errors are likely to be made.

In the first place it is not possible to infer with precision the true transformation temperature from the thermal curve, as the transformation temperature is always higher than the decalcescence point, and also depends upon the rate of heating.

In the second place the hardener is certain to underestimate the lag of temperature between the steel and the pyrometer. At the end of 45 minutes a 40-pound mass of steel has been found to be over 100 degrees below the temperature of the pyrometer placed in close proximity to the steel.

As the result of these two sources of error it is probable that the operators think they are over-heating the steel to attain their ends, when in reality they are only just heating it to the non-magnetic condition, and when they attempt to stop the heating at the temperature supposed necessary for a smaller mass they are really stopping the heating much sooner than they suppose.

Employing a 12-inch Wild-Barfield radiation furnace fitted with magnetic detector, masses of 40 pounds are now being hardened as a regular routine. Perfect hardening is being obtained, and there is no reason for supposing that larger masses than this cannot be successfully dealt with. In general the larger the mass the greater the difficulty of arriving at its temperature, and the more necessary becomes the employment of some device or other such as the magnetic detector, which tells one when the last grain of steel has completed its transformation.

AUTOMOBILE RACE FOR THE STEEL TREATERS CONVENTION

George Desautels, chairman of the entertainment committee for the convention and exhibition of the American Society for Steel Treating in Indianapolis, September 19 to 24, has issued an announcement of a match race between Frontenac and Duesenberg automobiles. This 50-mile race will be staged on the speedway, Wednesday, September 21, at 10:00 A.M. This is the first time in the history of the speedway that the authorities have ever consented to let anyone stage a race of any kind on this track other than the annual race meet on Decoration Day. There will be three or four Frontenac cars and three Duesenberg machines. The manufacturers of these machines are located in Indianapolis and are great rivals. Other races are possible.

While the race will probably be the largest event and probably of the greatest interest to the visitors, Chairman Desautels has, nevertheless, arranged for golf and tennis tournaments and ball games between the Eastern and Western delegates. Dances, smokers, vaudeville and a continual round of enjoyment are promised for the visitors. The steel treaters are looking forward to having the largest convention and most enjoyable occasion in their history. Prospects for technical papers are up to expectations. The hotels are already reporting heavy reservations for the week of September 19.

The Logic of Roll Design

The Proportion of Wabblers to the Size of the Neck for Various Type Mills Are Considered—All Rolls Used In Similar Mills Could Be Standardized If Reason Rather Than Prejudice Were Used.

By W. H. Melaney.

PART V.

ONE of the conditions which appear to the manufacturer of rolls as very senseless is the fact that in rolls of the same diameter to be used under exactly similar conditions, there is a great multiplicity of sizes in roll necks and wabblers.

In other words, if you should select six rolls of same diameter which were to be used on exactly similar work by six different concerns, you would rarely find any two of them made identically. Yet there is no reason why all of them should not be of exactly the same dimensions, with the exception of the length of the neck, as this dimension would depend more or less upon the design of the housing in which the rolls are to be used. The neck must be long enough to prevent any interference between the coupling box and any projection that might exist upon the side of the housing. The cross section and design of the housing determines the minimum length that this neck should be. However, all other dimensions, such as diameter of neck, size of fillet, length and cross section of wabblers could be very easily standardized for all rolls used on the same size trains or for similar service.

This would obviate the necessity of the roll maker from carrying such a mass of patterns for the various sizes. This seems particularly wasteful when one size would do very nicely.

It is true that various individuals have entirely different opinions as to the merit or demerits of the various shapes of wabblers for rolls. However, if a careful analysis of conditions were made of the five in common use, as illustrated in Fig. 1, it would be found that in very nearly every instance the difference in opinion is based on prejudice, rather than reason.

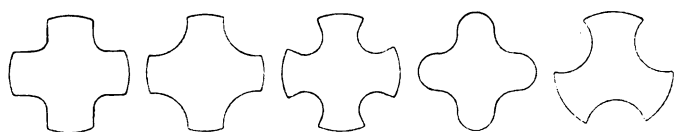


Fig. 1

The main essential of all these being that the coupling box, which is used to connect the driving spindle of the roll and which must continually change positions, due to the fact that the wabblers in most cases is just a rough casting and is rarely, if ever, exactly true with the neck. It must have a loose fitting coupling box in order to give a flexible connection. This box should have a firm bearing on the sides of the pods of the wabblers without lift, so that in driving the rolls under load there should be as little tendency as possible for the coupling box to grind or tear, and thus wear the wabblers out of shape. It must also have sufficient strength to transfer the power necessary to different rolling without breaking.

These conditions seem to be closely met by the straight cruciform wabblers as shown in cross section

Fig. 2. This type of wabblers is used more generally on modern mills than any other type. It is especially suitable on rolls over which hard service is required. The following tables have been based on this design as being preferable.

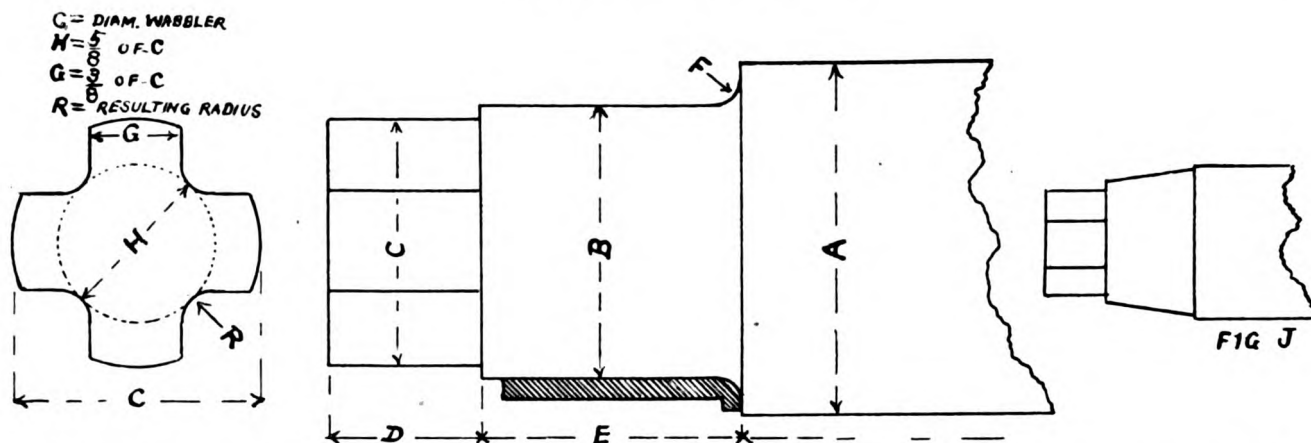
Using the formulae as outlined in the previous article for determining the diameter of the neck of the various types of rolls and which, as stated, was based upon rolls in general use, and then adopting the formulae of nine-tenths the diameter of the neck as the diameter of the wabblers in order that the wabblers may be smaller than the neck, as most wabblers are not machined and offer no interference with the neck, the writer submits a formulae for laying out the section of the wabblers as advocated and used by a prominent maker of rolls and roll machinery in the Pittsburgh district. This method seems to cover the essential parts of good proportions and construction, as outlined above.

This type of wabblers presents a straight bearing surface to the jog of the coupling box that drives it and is free to change its position by a simple sliding action without any tendency to tear the sliding surface or lift the roll.

The wear is fairly uniform and there is little tendency for the wabblers to wear taper. This is especially true if the coupling box is properly designed and has a groove recess cast in the middle of its bearing surface so that the end of the wabblers and the end of the connecting spindle when in position projects into this groove. This should be in the center of the coupling box and should prevent any pressure being brought to bear on the end of either the wabblers or spindle by the jogs on the coupling box. This in turn prevents any tendency of the jogs on the coupling box to wear taper, Fig. 3-K. This also prevents uneven end thrust on the wabblers.

Another expedient sometimes resorted to in preventing the wabblers from wearing taper was to cast a groove about one-half inch wide around the depressed portion of wabblers where it joins the neck, but this presented troubles in casting and has generally been discarded as being unnecessary. Fig. 3-L.)

The tables shown in Fig. 2, based on the formulae there shown, with the odd fractions eliminated for convenience, are submitted by the writer as a step in the direction of the standardization of necks and wabblers for rolls of the various types. The lengths of neck in these tables were selected from those in common use, but, as stated above, will depend to a great extent upon the design of the housings in which they are to be used. The diameter of the neck must not only be large enough to give proper bearing surface and strength enough to transmit the rolling strain, but should also be of proper proportion to the body of the roll, so that the time of setting or congealing of the molten metal in the neck after the casting of the roll



GUIDE OR BAR MILL ROLL								
A	B	C	D	E	F	G	H	R
8"	1 1/16"	2 1/8"	4 1/2"	5"	1/4"	4"	6"	
9"	1 3/8"	3 1/8"	5"	5 1/2"	3/8"	4 1/4"	7"	
10"	2"	3 1/2"	5 5/8"	6 1/4"	1/2"	4 1/2"	8"	
12"	2 1/2"	4 1/4"	6 3/4"	7 1/2"	5/8"	5"	9"	
14"	3"	5"	8"	9"	3/4"	5 1/2"	10"	RESULTING RADIUS
16"	3 3/8"	5 5/8"	9"	10"	7/8"	6"	11"	
18"	4"	6 3/4"	10 3/4"	12"	1"	7"	12"	
20"	4 1/2"	7 1/2"	12"	13 1/2"	1 1/8"	7"	13"	
22"	5"	8 1/4"	13 1/4"	14 3/4"	1 1/4"	7"	14"	
24"	5 1/2"	9"	14 1/2"	16"	1 1/2"	8"	15"	
26"	6"	9 7/8"	15 3/4"	17 1/2"	1 3/4"	8"	16"	
28"	6 3/8"	10 1/2"	16 7/8"	18 3/4"	1 7/8"	8"	18"	
30"	6 7/8"	11 1/4"	18"	20"	2"	9"	20"	
32"	7 1/8"	11 3/4"	19"	21 1/2"	2 1/8"	9"	20"	
34"	7 3/4"	12 3/4"	20 1/2"	22 3/4"	2 1/4"	9"	22"	
36"	8"	13 1/2"	21 1/2"	24"	2 1/2"	10"	22"	
38"	8 5/8"	14 3/8"	23"	25 1/2"	2 3/4"	10"	22"	
40"	9"	15"	24"	26 3/4"	2 7/8"	12"	22"	

SHEET OR TIN MILL ROLL								
A	B	C	D	E	F	G	H	R
22"	17 1/2"	15"	7 1/2"	15"	1 1/4"	5 3/8"	9 3/8"	RESULTING RADIUS
24"	19"	17"	7 1/2"	15"	1 1/2"	6 3/8"	10 3/8"	
26"	21"	19"	8"	16"	1 3/4"	7"	12"	
27"	21 1/2"	19 1/2"	8"	16"	1 3/4"	7 1/4"	12 1/4"	
28"	22"	20"	8"	16"	2"	7 1/2"	12 1/2"	
29"	23"	21"	9"	18"	2 1/4"	7 3/4"	13 3/8"	
30"	24"	22"	9"	18"	2 1/2"	8 1/4"	13 3/4"	

DIAMETER OF NECKS AND WABLERS AS COMPILED

MERCHANT MILLS 16" DIAM AND UNDER — NECK = ROLL DIAM. $\times$ 0.625
 " " OVER 16" DIAM — NECK = " " $\times$ 0.67
 PLATE MILLS — NECK = " " $\times$ 0.75
 SHEET AND TIN MILLS — NECK = " " $\times$ 0.8
 BLOOMING MILLS — NECK = " " $\times$ 0.5625
 WABLERS ON ALL MILLS = DIAM. OF NECK $\times$ 0.9

ODD FRACTIONS ELIMINATED

FIG 2

will not take place so rapidly that it will set up undue casting strains between the neck and body of the roll, and thus render the roll more susceptible to breakage than if proper proportion had been observed.

This brings another feature into the problem of neck design, and that is the proper size of fillet to use at the point where the neck joins the body of the roll. The ideal condition of neck and body from a theoretical standpoint, and especially from the foundry man's point of view, would be to taper the neck from the full diameter of the roll to the final diameter of the neck as shown at J (Fig. 2). This would give the strongest possible neck and set up the least casting strains, but would introduce a number of other undesirable features which would cause more annoyance than the conditions they sought to overcome.



FIG 3

Therefore, the shape of neck as at present time used, that of a parallel bearing surface with the proper fillet at the juncture of neck and body has been selected as more suitably meeting all the conditions.

Rolls in use in rolling mills are not usually fitted with individual bearing brasses, as is true on other kinds of revolving machinery, but one set of rolls are removed from their bearings and another set of rolls are substituted on these same bearings whenever the occasion requires. These are expected to go into service and do their full quota of work without any change or preparation of these bearings for their new duties.

A straight parallel bearing has been found best suited for this condition, permitting the roll to shift endways within the limit allowed.

The fillet is simply a strengthening factor where the neck and body join and preferably should not be a part of the bearing surface. The fillet on the bearing brasses should have a considerably larger radius than the fillet on the neck of the roll so that the two surfaces do not meet, or more properly, the fillet on the brasses should be cut off at an angle of 45 degrees as shown in Fig. 2. This is desirable because any end thrust of the roll (and in most rolling problems this is a considerable factor) has a tendency to crowd the roll up on the fillet. If the fillet were a part of the bearing surface, the tendency would be to try to lift the roll off the parallel part of its bearing and thus give a very narrow bearing just on the fillet itself. The result would be a very hot streak around the fillet, sometimes hot enough to set the lu-

bricating grease on fire. If this condition were permitted to go on, it would eventually mean a cracked fillet, due to too rapid expansion, and, finally, a broken-off neck.

This condition very often occurs on sheet and tin mills which are run hot, although the crowding up on the fillet in this case is due to a different cause, usually from the stretcher rods being pulled up too tight, not allowing for full lengthening of the roll when it becomes hot. On ordinary sheet mills this amounts to one-fourth inch or more.

If the housings are not spread apart enough to allow for this lengthening and the tie rods prevent

any further spread, then the rolls crowd up on the fillet and a hot neck is the result.

On all rolls where end thrust is a feature, this thrust should be taken care of by the straight side of brasses above the fillet. Then there is no tendency to lift the roll.

This brings us back to the size the fillet should be, and it is obvious from the above that the fillet should be as large as is consistent, leaving sufficient straight side on the bearing brass to take care of the end thrust without excessive wear.

The fillets given in the table are based on this hypothesis.

Alternating Current in By-Product Plants

Two Papers Recently Presented Before Iron and Steel Electrical Engineers Compared — One Paper Covering the Use of Direct Current and the Other Alternating Current in By-Product Plants.

By W. V. DUNN,
Chief Electrician By-Product Coke Works,
Tennessee Coal, Iron & Railroad Co.,
Fairfield, Alabama.

IN presenting this paper, it is not the intention of the writer to boost either the one or the other systems of electrical current, but to first make clear the application of alternating current as applied in plants engaged in producing the by-products of coal, and then state such changes in the system that the writer would advocate were he called upon to build an entirely new plant.

The plant presenting the most concrete example to the knowledge of the writer is that of the Tennessee Coal, Iron & R. R. Company at Fairfield, Ala., it being exclusively an alternating current plant.

Plant Capacity and Products.

At Fairfield there are four batteries of 70 ovens each, built some 10 years ago, and two batteries of 77 ovens each, completed within the past year, making a total of 434 ovens, all of the Koppers type, with a consuming capacity of approximately 7,800 tons of coal daily and a production capacity of 5,200 tons of coke; 85 tons of ammonium sulphate; 75,000 gallons of tar; 93,000,000 cubic feet of gas. This on a 24-hour day.

All of this material is handled several times during the process of manufacture by machines electrically driven except the gas, which is exhausted from the batteries by means of turbine driven centrifugal exhausters and boosted to outgoing mains with turbine driven centrifugal boosters.

Power Supply.

Alternating current at 6,600 volts, 25-cycle, 3-phase, transmitted from another works over two circuits of No. 4/0 stranded copper, is stepped down to 240 volts. Six 300 kva transformers being used with three 300 kva transformers as spares.

Power Used in Plant Proper.

Alternating current, 240 volts, 25-cycle, 3-phase, is the system used in the plant proper except the lighting,

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which is 110 volts, 25-cycle, 3-phase, and an isolated pumping station which is furnished from still another source at 6,600 V. 60-cycle, 3-phase, and is stepped down to 2,300 volts. This is merely a water recovery proposition and will not be considered further in this paper.

Motor Equipment.

The motor equipment consists of 241 motors with a total rating of 6,284 hp, and in this list will be found the various types, synchronous, squirrel cage and the slip ring, of which many are mill type; the slip ring motors having both the open and semi-open rotor slots, which detail will be referred to in another part of this paper.

Method Used for Transmitting Power from Sub-Station to Distributing Points.

Power transmitted to the various parts of the plant distributing point is accomplished by using three conductor varnished cambric or paper insulated lead covered cables run in underground conduit, using both socket straight joint and drive straight joint, fiber duct. The duct ranges in size from 2 to 4 inches, the greater number being 4 inches. The size of the conductors 500,000 cm. Larger cables would be rather difficult to handle and especially so in long runs, where this size does not furnish sufficient carrying capacity, another cable is run and connected in parallel to the first. Duct lines having as many as 24 ducts carry a part of the cables, but this seems to be the maximum number as trouble may be experienced due to soft spots in the ground, causing the duct line to break. No duct line is allowed closer to the yard level than two feet, and preferably should be three feet. Man-holes are constructed of concrete and large enough to allow working space around cables after they have been drawn in place. In all cases spare ducts are provided sufficient for future requirements. This, within reason, should be laid at the time of the original installation, as it will be found a very expensive proposition to make addition to an underground conduit system.

As in all other plants, there are continuous running or conveying equipment and machines that operate inter-

mittently or as the cycle of operation of the plant requires. For convenience, the various operations may be divided into four groups as follows:

- First—Coal handling equipment—continuous.
- Second—Charging, pushing and quenching machine—intermittent.
- Third—Coke conveying and screening machinery—continuous and intermittent.
- Fourth—By-product equipment—continuous.

Coal Delivery and Equipment.

Coal is delivered to the plant in standard railroad cars of the drop bottom type, coming direct from the mines where it has been previously crushed and washed. Coal handling equipment consists of four incline belts that deliver the coal to bins directly over the batteries. Two of the conveying belts are driven by 75 hp squirrel cage motors and two by 50 hp motors of the same type. Two shaker feeds to each belt feed the coal onto the belt, each driven by a $7\frac{1}{2}$ hp squirrel cage motor. This operation is continuous and very suitable for ac motor. Very often the belts operate for 24 hours without stopping. Flexible couplings should be interposed between motor and gearing. They are of extreme importance and mean a great deal to the life of the motor.

Charging, Pushing and Quencher Machines.

These machines and their duties are:

Larry cars which travel over the tops of the ovens on a track provided for this purpose, taking a weighed charge of coal from the bin before mentioned, and discharging it through doors in the top of the oven. When the oven is nearly full, the pusher leveling ram is run back and forth through a small side door, near the top of the oven, which uniformly levels off the charge. After the coking process has taken place, door machines remove the oven doors on each end of the oven. A guide attached to the door machine on quenching side is placed in front of the oven.

The quencher, or receiving car, handled by an electric locomotive, is placed to receive the coke. The pusher ram is then run through the oven, pushing the coke through the guide and into the car, from which it is dumped, after quenching, onto a receiving wharf.

There are one coal larry, one pusher and two door machines for each of the six batteries, while one locomotive serves two batteries for handling the coke.

Each larry is driven by a 30 hp slip ring motor.

Each pusher has one 30 hp slip ring motor, driving the leveler ram; one 75 hp slip ring motor, driving the coke ram, and one 75 hp slip ring motor for bridge drive.

Each door machine is driven by one 12 hp slip ring motor. The door extractor of each machine is driven by one 12 hp slip ring motor.

The electric locomotives are equipped with two 50 hp slip ring motors. These machines are classed as doing intermittent service, their greatest distance of travel is limited to the length of two batteries, approximately 600 feet, and work back and forth very much like the charging car on an open hearth or reheating furnace floor crane. The power developed by these motors is by no means fixed, very often they are momentarily overloaded and often go to the pull-out point.

The method of getting current to these machines is quite a problem and doubly so for the reason that it is necessary to have three conductor rails with a safety

shield under them and in some cases a guard angle on each side of the conductor. However, we think the problem has been successfully dealt with.

All of these machines are fed in two battery units through a set of conductor rails located above the oven doors in some cases, in other cases on columns supporting the battery platforms, and insulated with oak blocks which give very good service unless continuously wet.

If direct current motors were used a good saving would be effected on rails, insulators and supports. Also labor fabricating and installing, as only two rails would be required.

Coke Conveying and Screening.

Coke dumped on the wharf before mentioned is fed onto inclined belts which elevate it to a sufficient height to allow it to pass over a rotary grizzly screen, which removes the domestic coke and braize. The furnace coke being loaded into standard cars for shipment.

The equipment consists principally of belts, and screens, and are driven by squirrel cage motors and, in some cases, mill type motors are used. Very often belts are shut down fully loaded when changing cars at the loading end. In such cases, the motor starts up under full load. This complicates the classification between intermittent and continuous service.

In all such screening stations completely enclosed motors of either mill or mine type should be used. The dust and dirt from the coke has a most disastrous effect on the insulation of the winding.

By-Products Equipment.

The gas, the product from which the tar, sulphate of ammonia and benzol is taken, as before mentioned, is exhausted to the by-product building by centrifugal exhausters, electricity playing no part other than controlling the pressure in the mains by means of a governor, which consists essentially of a motor operated valve, the motor being controlled by a pontoon switch.

Pumps—Pumps ranging in size from 6 x 8 duplex to 16 x 16 triplex, the larger having a capacity of 1,500 gallons of tar per minute, aggregate a total of 400 hp motors driving pumps through silent chains are of sizes from 15 to 75 hp of the squirrel cage type, except the 16 x 16, which is driven by a 100 hp slip ring motor with flexible coupling. Their duty is to circulate tar through the gas mains for cooling the gas, also to transfer to different tanks such tar that has passed certain elimination processes. This is continuous duty 24 hours per day and all such drives should be equipped with ac motors.

Ammonium sulphate from dryers delivered on belt, conveyed to storage room where drag conveyors distribute it over storage space. These drives are usually small and require small continuous running motors from 5 to 10 hp, squirrel cage type. All precautions should be taken to prevent grounds, short circuits or anything causing a spark in these buildings.

Voltage of over 250 should not be allowed, and lighting preferably 110 volts.

Auxiliary drives around the benzol plant are steam driven due to the high inflammatory nature of the products. Lighting fixtures should be vapor-proof; metal conduits with sealed joints, and all conduit fittings should be thoroughly closed. Nothing over 110 volts should be allowed and switches should be mounted outside of building.

Cold Storage.

A reserve supply of coal necessary for Sunday and holiday operations is taken care of by a recently constructed stocking and reclaiming system, consisting of one Robins Bridge and several belt conveyors. The bridge span is 200 feet, travel of bridge 1,300 feet. This space constitutes the storage. Conveyors deliver the coal to trunk conveyor running the length of the storage and is then transferred to stocking conveyor or bridge from where it goes into storage. In reclaiming, the bridge grab bucket picks up the coal, dumps it into a hopper located on the bridge trolley and over the bridge reclaiming belt, from this belt onto main trunk conveyor to either of the incline belts.

Bridge and main conveyor driven by slip ring motor with magnetic control. Squirrel cage motor on all other conveyors in this unit, which consists of 12 motors, totaling 494 hp and consuming .33 kwh per ton stocking and .51 kwh per ton reclaiming.

An unusual feature is that the bridge has no line shaft connecting the end trucks, they being kept square by skew limit switches. No trouble has resulted from this feature. In case of trouble on any conveyor, except those on the bridge, the entire conveying system can be stopped from points 100 feet apart along the main conveyor. This prevents piling up of material.

Other Features.

Water for quenching the coke is furnished by one 3,000,000 gallon pump driven by a 100 hp squirrel cage motor, one standby unit as a spare.

Two Chicago pneumatic air compressors, 19 x 12 x 14 and 20 x 12 x 14 are driven by one 175 hp, 214 rpm and one 225 hp, 214 rpm. Synchronous motors furnish com-

pressed air for the plant. These machines have mechanical unloaders for controlling the pressure.

Shops—Line shafts and machine tools are driven by squirrel cage motors except one 36-inch lathe which is driven by a 15 hp slip ring motor.

In Conclusion.

All such machines that are not stationary, having several motors to be supplied with current from a collecting system and where they are grouped as mentioned as charging, pushing and quenching machines, should be direct current. These machines are usually started, stopped and plugged under load. All of this causes high current peaks. Collecting systems are cheaper to construct, cost less to maintain, with resultant less trouble, where there are two contact rails instead of three.

The wound rotor motors will start the load and do very good service but will not stand up under the same service that a dc motor will. That seems to be the conclusion of those engineers who select dc motor for their most severe mill drives, such as screw down, front and back mill tables.

Wound rotors with semi-open slots mean each conductor has a soldered connection at each end and these are responsible for the greater number of break downs within the motor. The cost of a motor generator set is an item, but so are the switchboard panels, cables and switches, as well as other items which cost more for ac than dc. With an ac motor, the speed remains constant, whereas the acceleration above normal speed of the dc motor would prove of some advantage in many cases.

The cost of the equipment will not vary very much and if any, it would be in favor of the direct current.

A double system, using both alternating and direct current seems to be the best solution.

Direct Current in By-Product Plants

By E. P. WINTERS.

The by-product coke industry has made great strides in this country during the past ten years, and is yet perhaps in its infancy.

There are a number of types and designs of these ovens, but the general arrangement and cycle of operation of each type is very similar, and requires practically the same class of machinery for its operation.

The coking process consists in the distillation of coal in a closed oven from which the air has been excluded.

The usual oven is constructed of silica brick and has approximately the following dimensions: length 39 feet 6 inches, height 9 feet 10 $\frac{5}{8}$ inches, and its walls are tapered from a width of 19 $\frac{1}{2}$ inches on one end to 17 inches at the other.

During the coking process the ends of the ovens are sealed with doors held in position with suitable clamps.

The coal coming into the plant is delivered by means of a conveyor belt to a storage bin directly over the battery of ovens. Having reached this point it is dumped into a larry car which runs on a wide gauge track the width of which is about three-fourths the length of the

oven. The larry then runs to a point directly over the oven to be filled and deposits its load through the charging holes in the top of the oven.

The usual amount of coal held by each oven is 12 $\frac{1}{4}$ tons, and it is of great importance that the coal be distributed evenly along the entire length of the oven. This requires some mechanical means of spreading or leveling as the coal is poured in through the charging holes. This is accomplished by a machine having the combined functions of leveler and coke pusher. The leveling arrangement consists of a long bar which travels horizontally through the oven near the top, and is repeatedly carried back and forth until the coal has been completely discharged from the larry and the oven is filled and leveled.

After the carbonization process is complete, the product is ready to be removed from the oven, quenched, screened and delivered into railroad cars for shipment.

Most of you are familiar with the general operation of a coke plant, but it is reviewed here in a general way just as an introduction to the discussion of properly deciding upon the equipment to be used.

In considering the electrification of by-product coke plants, let us first examine the load characteristics of the

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various operations with a view of selecting drives which have characteristics most nearly conforming to the duty requirements.

Let us take first that class of machines which require the use of mill type and railway type motors. The most conspicuous of these is the pusher and leveling machine. This machine usually has four motors, namely, the ram driving motor, the leveler motor, the machine travel motor and in most instances a door machine motor. Of these, the ram motor is the larger and has the heavier duty to perform. Here we have approximately $9\frac{1}{4}$ tons of coke to be pushed a distance of about 37 feet. The load is greatest just as the beginning of the operation, that is, the greatest amount of force must be applied at this time to start the mass of coke on its journey to the quenching car. The load becomes less as the ram head moves forward, due entirely to the fact that a lesser amount of coke remains to be handled; the amount of inertia stored into the moving parts being negligible.

Just here it might be well to mention one point which is likely to be overlooked, and that is the expanding properties of different coals in the process of coking. In the immediate district we are very fortunate in having a coal which shrinks perceptibly during carbonization, thereby clearing itself from the oven sidewalls. In some of the Northern plants this condition is not so favorable and the coke is held closely between the walls until the pusher ram has exerted enough force to break it loose.

In the pushing operation then we should have a motor capable of great starting torque.

There are two classes of motors which may be considered, first, the direct current series motor, and second, the three phase slip ring alternating current motor.

The characteristics of these two motors are too well understood to be reviewed at length in this discussion. However those features which have a direct bearing upon the case under consideration will be pointed out.

In the direct current series motor the maximum torque occurs in starting. The torque developed by this motor decreases with increasing speed and increases with decreasing speed. Under heavy load it slows down, thus relieving the power station of wide load fluctuations.

The polyphase induction motor is essentially a constant speed motor. It operates over a certain limited range of speed. It cannot exceed its synchronous speed, and when operating below its normal speed, it is less efficient. That is, when operating below normal rated speed, which can be done by introducing resistance into the rotor winding, this motor wastes that part of the power corresponding to the difference between the synchronous speed and the speed at which the motor is running. In other words, the induction motor, in order to produce a given torque uses the same amount of power at low speeds as it does at high speeds, although the power delivered to the machine which it is driving is reduced in proportion to the speed, and a corresponding loss in motor efficiency is effected.

The speed-torque characteristics of the induction motor is somewhat variable and dependent on sizes and types, but for a motor such as would be used for pusher service, the maximum torque would be developed when the motor is running around 70 per cent of its synchronous speed.

Moreover the alternating current motor does not produce nearly so active a machine as does the direct current motor, and this brings us to the consideration of the requirements of the leveler drive.

The leveler bar must be introduced into the chuck hole of the oven door, speed up quickly to about 90 feet per minute, stop, accelerate quickly in the reverse direction, and repeat this cycle for a number of times, depending upon certain local conditions. The induction motor cannot handle such a load so actively as can the direct current series motor, because the direct current series motor has a higher starting and accelerating torque and carries this high torque up to considerable speed.

Then comes the machine travel motor. The requirements of this drive are much the same as in the case of the electric locomotive. The machine is very heavy and bunglesome, and requires a high starting torque to get it under way. Here again the direct current series motor has the advantage.

The door machine motor, while only 5 to $7\frac{1}{2}$ hp in size, has a duty cycle which is intermittent and which would be best taken care of by a direct current series motor, but would naturally receive the same class of motor as provided for the pusher and leveler, as it is mounted upon the same machine.

Then we have what may be regarded as the next most important machine, and that is the locomotive pulling the quenching car which receives the coke as it comes from the oven.

This is usually in the neighborhood of a 20-ton locomotive and handles a car weighing about 60 or 70 tons.

It is not my intention to exploit the field of electric locomotive propulsion in this discussion, but I wish to point out the one outstanding fact which applies to this specific case, and that is this: if the three phase induction motor is adaptable to any class of electric locomotive service, it is not to the locomotive which starts and stops at very frequent intervals. The locomotive in our case must make four starts and stops for every oven pushed.

It might be said just here that one of the most common errors in specifying electrical machinery for by-product coke plants is to buy an express locomotive to do a switching locomotive's work.

Many plants are using a locomotive, the normal speed of which is ten miles an hour and more, when four or five miles an hour is plenty, and very much more satisfactory. This locomotive must carry the usual air compressor equipment capable of pumping about 100 cubic feet of air per minute for use of air brakes both on locomotive and quenching car, and to operate dump gates of quencher car.

The larry car really is an electric locomotive and the foregoing discussion applies to this piece of apparatus.

The only remaining motor drives of any great importance immediately around the ovens are the gas and air reversing machines.

There is no particular reason why we should distinguish between the advantages of alternating and direct current motors on these drives. If we are using an alternating current system of drives for the pusher, larry and locomotive, then the reversing machines should also be driven by alternating current motors. If we are using direct current to drive the principal machines, then we may as well use direct current for the reversing machines, for these motors only operate through a period of time of about 30 seconds every 15 to 30 minutes; so the size of motor generator sets, for producing the supply of direct current for the system, will not have to be increased.

As to controls for these drives, several types are in use. For the larry car a simple drum controller is all that is necessary, as is also true of the machine travel motor on the pushing and leveling machine. The leveling motor should be automatically accelerated by magnet switches, the operator controlling the starting and stopping by a simple reversing master controller. The leveler motor should be equipped with a solenoid brake which brings the bar to a quick stop when the current is taken off the motor. There should also be limit stops to prevent overtravel at either end of leveler bar.

The ram motor is very often controlled by a simple drum controller, but here, automatic acceleration is much to be preferred. Some plants have even gone so far as to equip this control with automatic slow down devices to prevent the ram gaining speed before the ram head presses against the face of the coke; then again to give slow speed as the last few feet of travel is reached. This drive should also have a solenoid brake and limit stops to prevent overtravel. The door machine may be controlled by a small face plate controller with very satisfactory results.

The locomotive may have a simple drum controller or magnet switches actuated by a master controller. The drum controller however is very satisfactory for the two motor locomotive.

The gas and air reversing motors are usually automatically controlled and their intermittent operation is actuated by a contact making clock. Push buttons are also provided in case the clock mechanism fails.

The hp ratings of the various oven drives will vary somewhat with local conditions, but the following list gives an idea of about the average size of motors used for the several operations: ram drive, 50 to 60 hp; leveler drive, 25 to 30 hp; pusher travel motor, 25 to 30 hp; door machine motor, 5 to 7½ hp; gas reversing motors, 5 to 7½ hp; damper reversing motors, 10 to 15 hp; larry motor, 25 to 30 hp; locomotive motors, 60 to 75 hp.

Other points which we must direct our attention include the difficulty and inconvenience of the three sliding contacts or current collectors used on three phase alternating current installations. With a direct current grounded system, only one current collector is necessary for each machine.

The current collector for the pusher is usually a shoe sliding along an insulated and protected rail.

The collector used in connection with the locomotive may be a slide shoe arrangement with the rail underneath the edge of the coke side bench, or an overhead trolley consisting of steel angle bars suspended from brackets protruding from the buck stays.

The larry car may have current collectors similar to that used in connection with the locomotive.

With reference to the various stationary motors used in connection with the plant facilities, there is no doubt that these should be induction motor drives. This includes shop motors, pump motors, conveyor motors and any others which have a constant speed load.

The substation should include transformers for lowering the pressure of the incoming power, and a motor generator set. Then there should be either a spare motor generator set or a steam driven generator to be used in case of failure of the motor generator set, or for use at such times as the source of power coming into the plant might be interrupted. This steam set is almost a necessity at times, for a ram or leveler bar may be left in an

oven until badly damaged. Then too, this set may provide light at times of power interruptions at night. This is more of a safety measure however, but is worthy of consideration.

The line feeders from the substation are usually carried on towers or structural work and then through conduits to the control switches near where the power is utilized.

I believe that practically all the by-product coke plants in this country are using 220 volt current around the ovens proper. This has become pretty well standardized, and rightly so. The distances the low pressure currents are to be carried are not long; and insulation is easier for this voltage, especially in control apparatus.

The alternating current supplied to stationary motors may be either 220 or 440 volts. 440 apparatus is very satisfactory and admits of smaller line conductors for delivering current to these motors.

In conclusion, I would like to say it is my belief that the foregoing ideas are basically correct for the electrical apparatus which is available at this time; and that while some plants may have certain local conditions which would lead to some concessions, the majority of recent installations have been made along the lines pointed out in this discussion.

BY-PRODUCT PLANTS MAKE NEW RECORD

Coke and by-product resources of the United States, as indicated by production and statistical information just issued by the geological survey, today are in the most favorable position since these industries were established. Production today is at a particularly low point, due to the general business depression, but the potential capacities, as shown by the government figures are generally considered as tremendous.

The output of coke from both beehive and by-product ovens in 1920 totaled 51,888,000 tons, the old style ovens producing 20,980,000 tons, or 40 per cent of the total, and the retort ovens 30,908,000 tons, or 60 per cent. In this performance, the by-product ovens produced their record tonnage, surpassing the 25,997,580 tons of 1918, the previous high year, by 4,910,420 tons. Compared with 1919, the 1920 output of by-product coke was 5,764,458 tons, or 23 per cent, greater. Beehive production last year exceeded 1919's output by 1,330,000 tons, still, however, being nearly 10,000,000 tons under the 1918 figure.

How coke production and percentages, both as regards ovens, compare for the past eight years, 1914 excluded, may be seen in the following table:

Year	—By-Product—		—Beehive—		—Total—
	Net Tons	Pct.	Net Tons	Pct.	Net Tons
1913	12,714,700	27.5	33,584,830	72.5	46,299,530
1915	14,072,895	33.8	27,508,255	66.2	41,181,150
1916	19,069,361	35.0	35,464,224	65.0	54,533,585
1917	22,439,280	40.4	33,167,548	59.6	55,606,828
1918	25,997,580	46.0	30,480,792	54.0	56,478,372
1919	25,143,542	56.1	19,650,000	43.9	44,793,542
1920	30,908,000	60.0	20,980,000	40.0	51,888,000

The by-product coke output last year was from 11,038 ovens, according to the geological survey. This was 659 more ovens than produced the 25,143,542 tons in 1919. In the number of ovens, Pennsylvania heads the list with 3006, or 160 more than in 1919. Ohio is second with 1658 ovens, an increase of 50 in a year.

In production, Pennsylvania last year had an output of 7,710,000 tons of by-product coke, an increase of 1,837,000 tons, or 39 per cent.

Electric Furnaces for Making Steel

General Features and Advantages of Girod Furnaces—Report on
Girod Furnace Located In Plant of Bethlehem Steel Company
Published in Full — Electric Steel-Making Furnaces Classified.

By ALFRED STANSFIELD, D.Sc., A.R.S.M., F.R.S.C.*
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PART VI

THE Girod furnace was the earliest example of the electrode-hearth arc-furnace for use in commercial steelmaking, as it dates from the year 1905. It may be remembered, however, that Siemens's vertical arc furnace,* which is of this type, was used experimentally as early as 1882 for melting steel.

The typical Girod furnace is a tilting furnace, either circular or square in plan, having one central electrode entering through the roof and six water-cooled steel contacts passing through the hearth. While in operation the upper parts of these steel rods become melted, but the lower parts remain solid. When the steel has been poured, enough molten steel will usually remain to renew the contact rod as it solidifies. It will be difficult, however, to repair the hearth without danger of covering up the steel rods and so preventing the contact when the furnace is again started. The earlier Girod furnaces were square in plan, as is shown in Fig. 29, but more recent furnaces have been made circular. The latter design is better, as there is less wall area for a given volume, and, with a single electrode, the wall is heated evenly at every point, which is not the case with a square furnace.

The Girod furnace, in comparison with a series-arc furnace, is considered to have an advantage in the melting of cold scrap, because a large electric current at a low voltage will flow from the electrode evenly through

the pile of scrap, thus heating and melting the scrap by resistance heating as well as by the arc. When the metal has melted, the electric current will flow in a somewhat horizontal direction through the molten metal from the central electrode to the four contacts which are located at the corners. This electrical flow will cause an electromagnetic circulation of the molten metal. Paul Girod mentions the "thorough electrification" of the steel as one advantage of his furnace, meaning that the electric current passes down through the steel, instead of merely skimming the surface as it might be supposed to do in a series-arc furnace. In view of the low electrical resistivity of steel, the passage of the current through the main mass of molten steel can have very little heating effect, but some heat may be produced at the entrance to the contact plugs where the cross-section of the conducting metal is more restricted.

The early furnaces had a capacity of $1\frac{1}{2}$ or 2 tons and were operated at a low voltage of 50 or 60. The low voltage followed naturally from the fact that there was but one arc in the circuit. This low voltage supply will tend towards greater steadiness of operation when melting cold scrap, but it increases the cost of the electric power, which is always supplied more cheaply at high voltages. The added cost of low-voltage power may be considered under two heads. In the first place, for a certain number of kilowatts supplied to the furnace terminals, the current will be larger

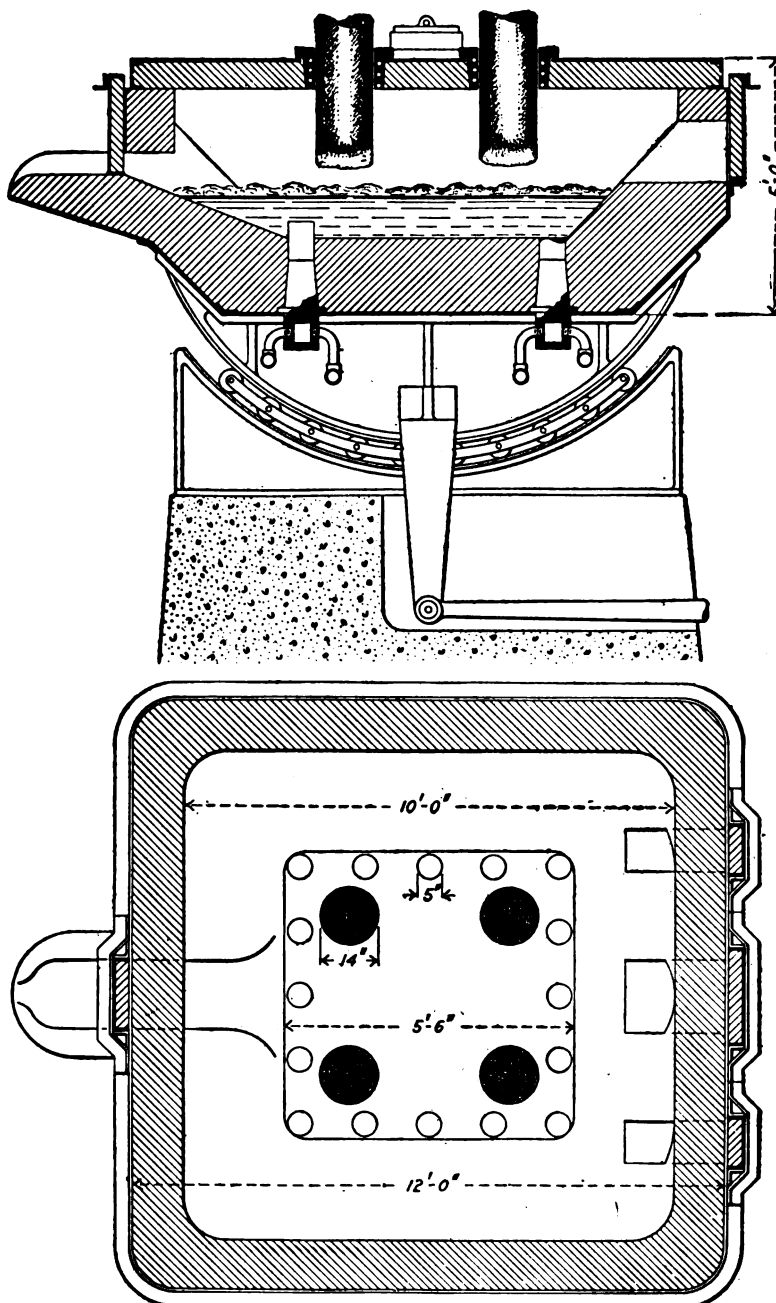


Fig. 29—Girod furnace with four electrodes.

*Stansfield, "The Electric Furnace," page 4.

as the voltage is less, and consequently the cost and heating losses in the low-tension windings of the transformers and in the bus bars and cables leading to the furnace will be larger. Apart from this we must consider the losses in the electrodes themselves. A simple series-arc furnace has two carbon electrodes and a voltage of about 100, while a simple Girod furnace has one carbon electrode and a voltage of 50 or 60. Considering the carbon electrodes only, the Girod furnace, with half the voltage and half the electrodes would have, for equal power, an exactly equal electrode loss, providing that the electrodes were properly proportioned.† The Girod furnace, however, has the additional loss from the steel electrodes which form part of the furnace hearth. The losses in these, if properly proportioned, will be decidedly less than in the carbon electrode, and if the Girod furnace employs about two-thirds the voltage of the series furnace, the combined electrode losses will be about equal in the two kinds of furnace.

A more serious difficulty in regard to the operation of the Girod furnace arises from the fact that not only the single-electrode furnace, but also the multiple-electrode furnaces, Fig. 29, employ single-phase current. Electric power in large amounts is usually supplied from a three-wire three-phase system, and single-phase furnaces can only be run satisfactorily in groups of three, operating together so as to draw an equal amount of power from the three phases of the supply. Another method which was adopted by Girod in his early work was to use a large single-phase generator giving current at a suitable voltage and driven by a three-phase or two-phase motor. This arrangement is entirely satisfactory from an operating point of view, though the electrical losses are greater than with a simple transformer, but entails a large initial expense for motor and generator.

Three-Phase Furnaces.

The larger sizes of Girod furnace are now arranged for use with three-phase current. These furnaces are circular in plan and are provided with three movable electrodes. The steel contacts in the bottom, of which there are as many as ten, are all connected together and to the furnace shell. The arms carrying the electrodes are supported by steel masts attached to two sides of the furnace, while the service transformers are placed below the working platform of the furnace, and are thus quite out of the way.

The wiring diagram in Paul Girod's paper (5) shows that the primary windings of the service transformers are connected in delta, and the secondaries in star, with their neutral point connected to the furnace shell and steel bottom contacts. It might be supposed from this that the furnace resembled, in effect, a three-phase Heroult furnace, and that the bottom contacts would not carry any current if the phases were in perfect balance. A closer examination of the diagram shows, however, that one of the secondary windings has been reversed, which gives the phase relationships of this furnace. In consequence of this reversal there must always be a flow of current through the bottom contacts, because the currents entering the three electrodes do not balance each other. The amount of current flowing through the contacts will not, however, be equal to the current flowing through the upper electrodes, as in a single-phase fur-

nace, but will be equal to the effective sum of these at any moment, that is twice the flow through any one of the electrodes.

The Girod furnace is made in sizes up to 15 tons. It is in use in a few American plants and in a number of European works. The following particulars of its operation were given a few years ago by Messrs. C. W. Leavitt & Co. of New York:

The power required is 175 kw per ton when melting cold charges in sizes up to 5 tons, and 150 kw in sizes of 6 tons and over. For refining molten steel, 125 kw per ton up to 5 tons capacity and 100 kw per ton in sizes of 6 tons and over. The current for small furnaces may be continuous or single-phase alternating, but for furnaces of 6 tons and over, three-phase current is used. The voltage is 65 in furnaces up to 4 tons capacity and 70 in furnaces of 6 tons and over. The frequency of the current may be as high as 50 cycles, but a lower frequency, such as 25 cycles, is preferable, and enables the power factor to be at least 80 per cent.

The length of each heat is about 7 hours when melting a cold charge and refining the steel, and from 1½ to 2½ hours when refining a molten charge. A furnace with one electrode can be used for 2½ tons of cold charge or 3 tons of molten charge. A furnace with two electrodes can be used for 5 tons of cold charge or 6 tons of molten charge. A furnace with three or four electrodes will treat 12 tons of cold charge or 15 tons of molten charge.

The electrodes are made large enough to limit the current density to 5 amperes per square centimeter, that is 25 amperes per square inch of cross section; referring, of course, to carbon electrodes. The electrode regulation is automatic even from the beginning of melting a cold charge. The furnaces tilt both forwards and backwards for pouring the steel or skimming the slag. The tilting machinery is either electric or hydraulic.

The cost of a furnace complete, with one roof and with electrode regulators and tilting machinery, but without electric generators or transformers is as follows (in pre-war prices):

1 ton furnace	frs. 13,000	= \$2,600
2½ ton furnace	frs. 18,000	= 3,600
4 to 6 ton furnace	frs. 25,000	= 5,000
8 to 12 ton furnace	frs. 35,000	= 7,000

The following particulars were given with regard to a furnace of 12 tons capacity in a European plant:

Maximum power needed, 1,200 kw. Power supply recommended, a 1,500-kva single-phase generator, 25 cycles, 75 volts, with regulation between 65 and 85 volts, allowing for an 85 per cent power factor. A transformer may be used instead of a generator, but it should have a larger capacity, so as to allow of a range of voltage and current.

Length of a heat, 7 to 8 hours with a cold charge, or 1½ to 2½ hours with a molten charge. Power employed varies between 900 and 1,200 kw. Energy consumed, 900 kwh per ton with a cold charge, or 150 to 250 kwh per ton with a molten charge.

Electrodes, four of 14 inches diameter weighing 600 pounds each. With cold charges these last about 10 heats, corresponding to a loss of 22 to 30 pounds, or 90 cents per ton of steel. With hot charges they last about 20 heats giving a consumption of 9 to 11

†Stansfield, "The Electric Furnace," page 99.

pounds, or 35 cents per ton of steel. These figures include the unused stub ends. At the present time threaded electrodes would no doubt be used so as to avoid this loss.

With cold charges the roof lasts for 20 to 30 heats, and the furnace lining from 30 to 40 heats. With molten charges the roof lasts for 40 to 60 heats and the lining from 60 to 90 heats. The roof can be replaced in 15 minutes, but repairing the furnace lining takes about 36 hours.

The cost of the furnace repairs amounts to \$1.60 or \$1.70 per ton of steel using a cold charge, or to \$1.20 or \$1.50 per ton using a molten charge. Six men are needed to attend to this furnace assuming that the materials of the charge are brought to the furnace without their assistance.

At an American works making high-grade steel the power consumption was 900 to 1,000 kwh per ton and the other expenses, when melting and refining cold charges, were:

Labor	\$0.80 per ton
Furnace upkeep	2.20 per ton
General expenses	.80 per ton
Electrodes	1.00 per ton
	\$4.80 per ton

The following account (6) of a 10-ton furnace in the electric furnace department of the Bethlehem Steel Company was published in 1916; two more furnaces of the same size were to be added.

The furnace is circular in plan, 15 feet in diameter and 5 feet deep outside, of $\frac{3}{4}$ -inch steel plate. It has one charging door opposite to the spout. The furnace rests on rollers and is tilted by means of a 15-hp reversing motor. It tilts towards the charging platform to discharge the slag, and in the other direction to pour the steel into a ladle. The furnace hearth, made of well-burnt magnesite or dolomite, is 20 inches thick, and the molten steel is about 16 inches deep.

Passing through the hearth, and connected electrically to the steel shell, are fourteen $3\frac{1}{2}$ -inch steel electrodes or pole pieces. Their lower ends are water cooled. The roof is an arch of 9-inch silica bricks and the hearth walls are built of magnesite bricks. Three 18-inch carbon electrodes are used, having a working length of about six feet. They are supported by water-cooled copper holders. The lower end of each electrode, while in operation, will be about 4 inches above the surface of the molten steel. The weight of this furnace is about 90 tons, including 35 tons of refractories.

The power is supplied from three 700 kva single-phase transformers. One terminal of each of these is connected to an electrode, and the other terminal to the furnace shell, which has heavy copper angles attached to it for distributing the current. Of the 700 kva supplied by each transformer, only 620 kva reaches the furnace, the rest being lost in heat in the conductors. The yield of finished steel is from 93 to 95 per cent of the cold materials charged, but the furnace is to be used largely for refining molten steel from 50-ton open-hearth furnaces or a 10-ton converter.

SILICON ADDITIONS TO STEEL

The effect of the time of adding silicon in the physical properties and the gas content of open-hearth steel is exhaustively discussed by E. Piwowarsky in Stahl und Eisen for June 10, 1920. An abstract of this important

article has been published by Technical Review, London, as follows:

A number of opinions are held regarding the deterioration of steel by the small quantities of silicon present in the ordinary commercial steels, principal among these being the view that the silicic acid formed by the action of the ferrous oxide is retained by the steel in the form of a finely divided emulsified product, and that this weakens the cohesion of the steel, while the excess of silicon impairs the weldability of the material. The writer carried out a number of experiments and observations in steel works, with a view to clearing up this question, and determining whether and how it would be possible to enhance the good effects of silicon and to suppress the deleterious effects. A number of test heats were made, and the silicon added (in the form of ferrosilicon) at different stages of the pouring. It was found that when the ferrosilicon was added too early, the silicon losses were considerable and the quantity of silicon left in the final product was smaller than when the addition was made as late as possible.

A further series of heats was carried out to determine the effect of the gases, incorporated in the steel, on its qualities. For this purpose, the melts were made, as far as possible, using the same material and the same furnace. The ferromanganese required for deoxidizing the bath was added when the charge was completed, and time had been allowed for a state of equilibrium to set in between the bath and the slag. The ferrosilicon in half the heats was added by placing it in the bottom of the ladle at the usual time and in the other half it was added as late as possible by means of a special box arranged over the ladle and fitted with a flap-door at the bottom. The quantities of silicon were so selected as to give a final percentage of 0.20 to 0.22 per cent in the steel, as it was found that only with these percentages was the difference between the methods of adding the silicon to the bath sufficiently marked to be observed.

The charges were cast in round chill molds of 540 kg. in sets of 34 ingots, except in the case of the heats containing over 0.5 per cent carbon, which were cast in 750 kg. square ingots. The ingots were always cast from the bottom. Before the steel was cast, the ladle was left standing for 10 minutes or so, this measure being necessary especially in the case of cold charges, as otherwise the rolling discard of the steel is increased, due to the presence of the "emulsified" silicic-acid in the steel. Gas samples were then drawn off by a special arrangement. The results show that the gases given off by the liquid steel, where the silicon is added prematurely, contain a very large proportion of CO, which is the most harmful gas as regards the formation of blowholes.

Rolling tests were also carried out to show the amount of discard resulting (from the presence of occluded gases) when the silicon was added early and late. The following table shows the results:

Test No.	C.	Mn.	P.	S.	Si.	—Results of Rolling—		
						Good Material, Kg.	Dis-card, Kg.	Dis-card, Pct.
(a) Ferrosilicon Added at Usual Time								
1	0.30	0.69	0.051	0.028	0.18	24,200	14,000	36.50
2	0.39	0.63	0.050	0.036	0.20	27,200	12,800	32.00
3	0.37	0.51	0.053	0.044	0.20	34,400	12,100	26.00
4	0.32	0.47	0.014	0.037	0.19	9,300	21,740	70.00
(b) Ferrosilicon Added Late								
5	0.36	0.54	0.027	0.038	0.22	30,250	6,800	18.00
6	0.35	0.57	0.043	0.032	0.24	32,700	3,700	10.00
7	0.31	0.52	0.057	0.038	0.25	28,600	4,900	14.60
8	0.40	0.54	0.027	0.040	0.26	36,200	4,100	10.00
9	0.37	0.58	0.064	0.040	0.25	34,900	3,800	9.80

Heat Treatment of Screw Stock

Prolonged Treatment at High Temperatures Is Necessary to Refine the Llamilar Structure Caused by Cold Rolling—Greatest Possibilities Lie In Case Carbonizing.

By A. A. BLUE, Metallurgist,
The Duff Manufacturing Co.

DUE to the ease with which it may be machined and to the fact of its generally being furnished in the cold rolled condition, the grade of steel known as "screw stock" is very popular with the machine shop man. Could it be heat treated to overcome its low physical properties, its field of usefulness would be largely increased.

secure the machining qualities which make it so desirable to the production man, the composition is intentionally specified in such a manner that would be rejected in any other grade of steel for heat treatment purposes. Thus, the S. A. E. specification known as No. 1114, is as follows: Carbon 0.08-0.20; manganese 0.30-0.80; phosphorous 0.12 maximum; sulphur 0.06-0.12.

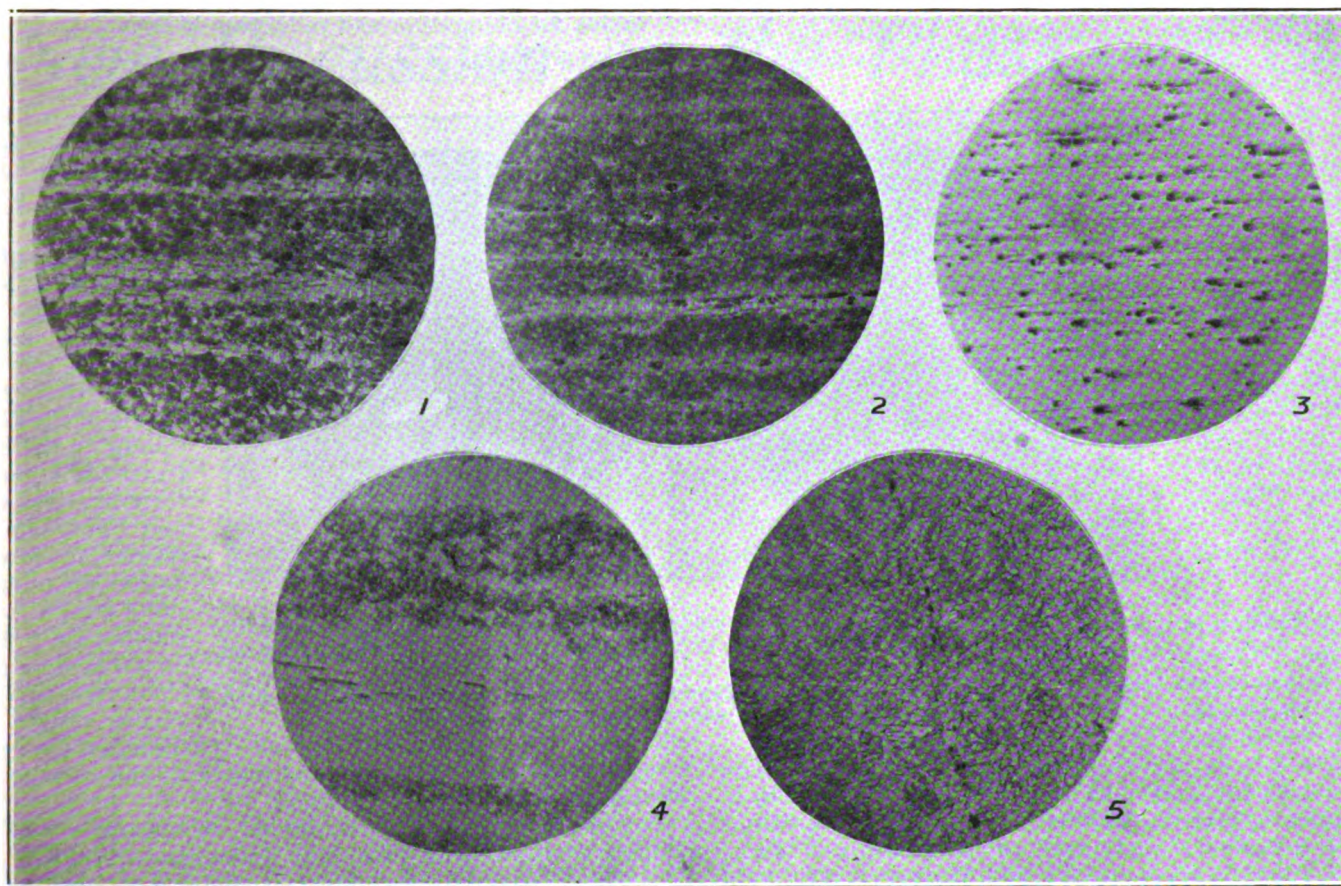


Fig. 1—Cold rolled screw stock etched in ten per cent nital. The segregation of ferrite with elongation of grain, due to first hot and then cold rolling, is at once noticeable.

Fig. 2—Same stock etched with Stead's reagent. The phosphorus segregation is clearly shown.

Fig. 3—Same sample as in Fig. 2 but unetched. The slag inclusions are clearly shown in this as well as in Figs. 1 and 2.

Fig. 4—Specimen heated to 1650 degrees F., held for three hours and slowly cooled. Equalization has just started.

Fig. 5—Specimen heated to 1750 degrees F., held for fifteen hours and quenched in running water. A practically uniform structure will be noted.

Difficulties To Be Overcome In Heat Treatment of Screw Stock.

However, it is under a number of great disadvantages from the points of view of mechanical strength and susceptibility to heat treatments of various kinds, as hardening and carbonizing. In the first place, to

Here are phosphorous and sulphur, which are ordinarily frowned upon in steel compositions, running about three times the amounts found in other grades, and the minimum for sulphur higher than the maximum in any other specifications. As is only too well known, these two elements of themselves in such large

amounts greatly reduce the strength of the steel. Further, the phosphorous has a large tendency to segregate the carbon and manganese, thus causing weakened areas in an already weak material. Add to these disadvantages the tendency of the steel manufacturers to use heats of steel for cold rolled screw stock, which are unfit for anything else, because surface defects can be covered up in the cold rolling operation. This also leads to the use of cropped ends from ingots for the same reason. The result is seen to be an almost hopeless proposition for the heat treater. However, by proper methods, a certain degree of improvement may be obtained by heat treating screw stock.

Fig. 1 shows the ordinary appearance of screw stock with an alcoholic nitric acid etch, under the microscope. The segregation of ferrite is at once noticeable, with the elongation due to first hot and then cold rolling. The excessive prevalence of slag should also be observed. Fig. 2 etched with Stead's reagent, shows the phosphorous segregation. Again the large amount of slag is apparent. The extent to which slag is often found in such material is more readily appreciated by an examination of Fig. 3, showing a sample of screw stock, unetched. The analysis of the specimens just described is as follows: Carbon 0.19; manganese 0.62; phosphorous 0.088 and sulphur 0.087; a typical screw stock composition.

Possibilities in Heating Treating

Turning now to the heat treatment of such material, it is seen that the possibilities in this line lie in a thorough breaking up of the segregation of ferrite in its laminated form. This is found to require a rather drastic treatment, involving high temperatures. Thus, Fig. 4 shows a piece heated to 1,650 degrees F., held for three hours, and cooled slowly, resulting in only the commencement of the necessary equalization. Fig. 5 is taken from a sample heated to 1,750 degrees F., held for 15 hours, and quenched in running water. This treatment has produced a comparatively satisfactory structure, although chains of slag are prominent.

The above treatments were carried out under laboratory conditions. In actual shop practice it has been found that holding at the quenching temperature of 1,750 degrees for one hour will produce results in keeping with the possibilities of this low grade steel. On parts approximately one inch in thickness, the following results may be obtained: Brinell hardness 170-207; scleroscope hardness 35-40. Tensile strength determinations were made on $\frac{3}{4}$ -inch rd. bars of the

following analysis: Carbon 0.16; manganese 0.56; phosphorous 0.098; sulphur 0.091. In the cold rolled condition this material showed:

Tensile strength	96,390 lb. / in ²
Elastic limit	44,710 lb. / in ²
Elongation	16.0%
Reduction in area.....	47.56%

The one redeeming feature of cold rolled screw stock from a point of view of mechanical strength is exhibited by the above figures. The cold rolling produces an excess of amorphous material between the grains of the steel, thus increasing its tensile properties. This is shown by the tensile and elastic limit figures given above which are high for such low carbon steel. Such results would not be obtained from hot rolled material of this low carbon content. It should be added, too, that the phosphorous aids in increasing these values. The effects of the phosphorous, sulphur, slag and segregation are apparent in the low values for elongation and reduction in area.

This treatment as given below, is seen to produce

an increase of somewhat less than 10% in tensile strength in a bar of this size. On parts of larger dimensions, however, the increase would be more noticeable for the reason that the effects of the cold rolling on the untreated bar penetrate to a less extent. This would result in lower figures for tensile strength and elastic limit before treatment. Upon treatment, as the effects of the quenching

would penetrate far into the material, the increased properties would be evident.

Another piece of the same bar was heated to 1,780 degrees F., held at heat four hours, and quenched in water. The following physical results were obtained:

Tensile strength	104,500 lb. / in ²
Elastic limit	45,000 lb. / in ²
Elongation	14.5%
Reduction in area.....	43.4%

Case Carbonizing Screw Stock.

Probably the largest field where heat treatment is attempted with screw stock is in carbonizing and case hardening. In this operation, as in ordinary hardening, the massive segregation of ferrite and pearlite is a great disadvantage. Fig. 6 shows a piece of screw stock cut transversely to the direction of rolling and carbonized on this surface at the ordinary carbonizing heat of 1,600 degrees F. for two hours. The result is at once apparent. Due to the unequal distribution of ferrite and pearlite on the surface, alternate bands of

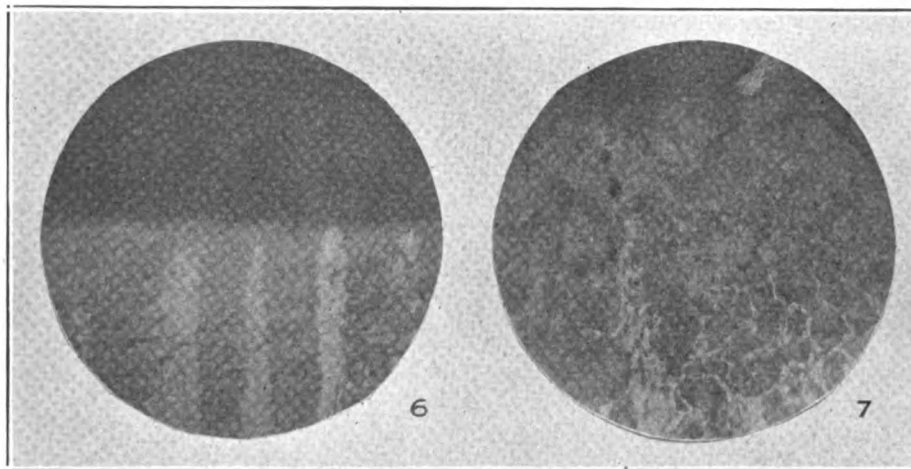


Fig. 6—Specimen of screw stock carbonized at 1650 degrees F., for two hours. Alternate bands of hard and soft steel are noted. Due to the segregation of phosphorus.

Fig. 7—Specimen carbonized at 1750 degrees F. for four hours. It will be noted that this structure is far superior to that shown in Fig. 6.

hard and soft steel are formed by the case hardening. This results in the hard and soft spots on the hardened surface, so often found in material of this kind. To avoid such a condition it is necessary either to first anneal the steel at 1,780-1,800 degrees or to carbonize at this temperature. The greater uniformity produced by the higher carbonizing temperature is shown in Fig. 7, carbonized at 1,750 degrees for four hours. High carbonizing temperatures should be avoided, however, as they produce a case sharply defined from the core, and not well graduated into the soft interior. Such cases chip off much more readily than those formed more evenly at lower temperatures. It should also be pointed out that effects of the high sulphur and phosphorous contents are much more pronounced when in combination with the high carbon produced in the case, and that all such case hardened articles will chip more easily than those made of low

sulphur and phosphorous steels. For this reason, deep cases on screw stock should not be attempted.

In dealing with high quenching and refining temperatures, as 1750-1800 degrees, the scaling produced in ordinary treatment procedure as carried out in the usual shop furnaces is quite large. This is also accentuated by the impure condition of the steel under consideration. Therefore, especial precautions should be taken to minimize this effect as much as possible.

Conclusions.

In conclusion, it may be said that ordinary cold rolled screw stock of the general composition covered by the S. A. E. specification No. 1,114, presents nearly all of the undesirable features for a steel to be heat treated. However, by the use of drastic treatments, it is possible to produce appreciable improvements in it. Such material should only be used for parts requiring the least service.

New Discussion on the Physics of Steel

Application in Rolling of Effects of Carbon, Phosphorus and Manganese on Mechanical Properties of Steel.

By WM. R. WEBSTER.

THIS is a contribution for the proposed new discussion on the physics of steel. The former discussion on the subject started with the consideration of five papers presented at the Chicago meeting in 1893, and continued for several years. The Suggested Lines of Discussion, prepared by Doctor Howe, covered a wide field and added greatly to the success of the work. Naturally, the first step in a new discussion will be to remodel and bring up to date the old Suggested Lines of Discussion so as to embody all the important advances in the metallurgy of steel that have a bearing on the physics of steel and keep the papers and discussions within the field of work undertaken. This paper will be devoted to the practical application, in rolling steel, of the effects of carbon, phosphorus, and manganese on its tensile strength, with some suggestions on further research work.

Dr. J. E. Stead, in his paper Influence of Some Elements on the Mechanical Properties of Steel*, gave a complete review of all that had been done during the past thirty years. He gave full credit to all investigators who worked on these lines, also their results, with his views on same, and in many cases his own results. All of this data and much new valuable information were put in convenient shape for reference and study. To do this required a great deal of work, which is fully appreciated by the steel manufacturers and investigators.

The variations in the values given by the different investigators for the increase of the tensile strength of steel for each 0.01 per cent of carbon, phosphorus, and manganese were largely due to the steels they worked on, the large or small variations in the amount of the elements present, and the omission to take into consideration all the factors, from the blast furnace through to finished rolled material, that affect the character of the

steel. For instance, a poorly made dirty steel requires considerably more carbon to give the same ultimate strength than a well-made clean steel with the same phosphorus and manganese content.

None of the values given for each element will apply equally well for all makes of steel or to different works making the same steel, yet each of us has contributed something to the fund of information that has enabled the present practical steel grading methods to be developed. Of course, the development of the quick chemical methods has greatly assisted in this work, especially the quick combustion for carbon determination, which has generally replaced the old color carbons, which at times were more or less guess work. Fortunately, several of our largest steel manufacturers have always relied on the work of different investigators and coöperated with them. These manufacturers deserve credit for this and the practical working tables that have been developed and put into daily use at their works. They can now grade their steel and roll it into the finished product with much greater certainty of its meeting all requirements of the standard specifications than formerly and with much less trouble than when they had to grade the steel from the results of the tension and bending tests of bars rolled from small test ingots from each heat of steel.

Should trouble occur under the present method of working, its cause is more easily located and corrected, as we now appreciate that uniform results can only be obtained by proper heating with proper reductions and medium finishing temperature in rolling. More good steel was formerly spoiled by too heavy reduction and by too high finishing temperatures in rolling than from any other cause.

Base for Structural Steel Calculations.

When bessemer steel was in general use for structural purposes, a base of 50,000 lb. per sq. in. (3515.4 kg. per sq. cm.) was taken, to which 1000 lb. (453.6 kg.) was added for each 0.01 per cent of carbon contained in the steel. This worked fairly well as a guide, the base

Note—Paper to be presented before Wilkes-Barre meeting, September, 1921, of American Institute of Mining and Metallurgical Engineers.

*Jnl. Iron and Steel Inst. (1916), 44, 5.

being high enough to include the effect of the average manganese and phosphorus contained in the steel, but the results of tension tests of bars rolled from small test ingots necessarily were used for grading the steel. When acid open-hearth steel came into use, the base of 50,000 lb. (22,679.6 kg.) was found too high. In 1885 Mr. Salom wrote as follows:

The influence of carbon on steel is better known than that of any other substance which enters into its composition. No one, however, so far as I am aware, has done anything more than formulate the general law that tensile strength increases with carbon, other things being equal. I have made the interesting observation that this increase is almost exactly 1,000 pounds for each 0.01 per cent of carbon. That is to say, assuming 0.01 per cent of carbon to be a unit of carbon, if to 45,000 pounds (20,411.7 kg.) (the tensile strength of pure wrought iron) we add as many thousand pounds as there are units of carbon, we shall be able to make a close approximation to the tensile strength. Boiler-plate steel, for example, has about 0.15 per cent carbon, and 15,000 plus 45,000 equals 60,000 pounds, or about the tensile strength of boiler plate steel, etc.

Of course this law only holds good where other things are equal. An undue amount of one or all of the foreign substances that enter into the composition of steel, or unusual physical conditions, would change the results entirely. It may be of value, however, as an indication that, when steel with a known amount of carbon does not possess a certain tensile strength, the other substances entering into its composition are present in undue proportion, or it must have been made under unusual physical conditions.

The above law is not applicable to castings, where the presence of so much silicon affects, in a notable degree, the tensile strength derived from a given amount of carbon, and the physical properties are also affected by the fact that the metal has not been worked.

Mr. Salom did not give any value for the effect of phosphorus or manganese, and the tension tests of bars from small test ingots were used, as before, for grading the steel and applying it on the orders.

The conditions were practically the same in 1892, when the writer began his investigation at the Pottstown Iron Co.'s works except that the introduction of basic steel, with much lower phosphorus, had shown that the base of 45,000 lb. (20,411.7 kg.) was too high. No additional information on the effect of carbon was available and the information on the effect of manganese and phosphorus was conflicting; the writers generally claimed that there was no relation between the chemical composition and mechanical properties of steel that could be relied on. This added to the interest of the problem undertaken.

Effect of Finishing Temperature and Thickness of Rolled Steel on Tensile Strength.

At that time there was no general knowledge of the effect of finishing temperature and of the thickness of rolled steel on its tensile strength; if the steel manufacturers had such information, they kept it to themselves. To determine these questions, to be used as a starting point, a large number of slabs from the same heats of steel were rolled into plates of different thickness; the finishing temperatures of these plates were kept as nearly uniform as possible for each thickness of plates rolled. The tension tests showed that there was a decrease of 1000 lb. per sq. in. for each increase of $\frac{1}{8}$ in. (3.17 mm) in thickness of plate from $\frac{3}{8}$ in. (9.52 mm) upward, and an increase of 1000 lb. for each decrease of $\frac{1}{16}$ in. (1.59 mm) down to $\frac{1}{4}$ in. (6.35 mm) thickness. This accounted for some 6000 lb. variation in the tensile strength of plates rolled from the same heat of steel, depending merely on the difference of the thickness into which the plates were rolled.

The importance of this is shown when we consider that there is only a range from about 45,000 to 85,000 lb. (3163.9 to 5976.2 kg. per sq. cm) tensile strength of steel used for structural purposes, and that 15 per cent of this 40,000 lb. difference is accounted for by the difference in the results from the same heat of steel when part is rolled into thick and part into thin material.

These results formed a good sound basis for all the work that followed and helped materially, as they covered the effects of about six to eight points of carbon. The writer at that time also found that the elongation and bending properties of rolled steel also depended greatly on the reductions in rolling, section rolled, finishing temperature in rolling, and rate of cooling. These points are well recognized today, and some of the mills take precautions in winter to keep the drafts of cold air from coming in contact with hot steel on their cooling beds; this is more important for the high than for the lower carbon steels.

The values referred to are in general use today with slight modifications to meet the special conditions at the different mills and the classes of material rolled. Some of the mills now follow a more direct method and, from their own records, increase the carbon as the thickness of their material increases on the same general plan as Doctor Stead refers to:

In works where ship and boiler plates are produced, widely varying results are obtained with the same steel if it is rolled into plates of varying thickness, but this is due to mechanical work and variation in finishing temperature. The more work and the lower the finishing temperature, the higher will be the tenacity.

In order to get the same static tests in ship plates of varying thickness, the carbon must be higher in the thicker plates. For instance, to meet Lloyd's specification and tests the relation between carbon and thickness of plate is as follows

Per Cent	Inch
Carbon...0.12 to 0.14	Thickness of plate...3/16 to 5/16
Carbon...0.15 to 0.17	Thickness of plate... $\frac{3}{8}$ to $\frac{1}{2}$
Carbon...0.17 to 0.21	Thickness of plate... $\frac{1}{2}$ to 1
Carbon...0.21 to 0.24	Thickness of plate... 1 to $1\frac{1}{2}$

If all these plates were normalized at 900° C. and cooled at the same rate, the tensile properties would vary proportionally with the carbon.

This table shows that a wide range of carbon limits must be used to keep the ultimate strength of plates from $\frac{3}{8}$ to $1\frac{1}{2}$ in. (9.52 to 38.099 mm) in thickness within the required limits of the specifications. Particular attention is called to this, as some engineers still hold to the old idea, and claim that steel from the same heat should meet all of the requirements of their specifications, irrespective of the difference in thickness of plates or weight of shapes that it may be rolled into.

Webster† estimated the ultimate strength for pure iron, if it could be obtained, as 38,000 lb. per sq. in. (2671.7 kg. per sq. cm) and to this base added the effects of the other elements. This low base for pure iron was confirmed, in 1895, by Campbell‡ when he used 37,430 lb. for basic steel and 38,600 lb. for acid steel, and more recently by Arnold, Brinell, Stead, and others, which is very gratifying to the writer.

†Trans. (1892) 21, 766. Webster's first paper. The effects of carbon, manganese and phosphorus are taken from the same paper, the effect of sulphur not being considered, as most of the more recent investigations by others have shown that the effects of the ordinary content of sulphur are negligible.

‡H. H. Campbell: "Manufacture and Properties of Iron and Steel." New York, 1904. Eng. & Min. Jnl. Co.

Webster's value of 800 lb. per sq. in. (56.25 kg. per sq. cm) for each increase of 0.01 per cent carbon was confirmed by Campbell in his second investigation, in 1904, when he used 770 lb. for carbon by combustion and 820 lb. for carbon by color for basic open-hearth steel. Doctor Stead gives carbon an effect of 870 lb. per unit of 0.01 per cent. All of these values are considerably lower than the old value of 1000 lb. per unit for all makes of steel.

Webster's values for the effect of 0.01 per cent phosphorus starts with 800 lb. per sq. in. in the presence of 0.08 per cent carbon and increases to 1500 lb. (105.5 kg. per sq. cm) in the presence of 0.15 per cent carbon or over, that is, from the same effect as carbon to 1 7/8 times the effect of carbon.

Campbell, in his first investigation, gave 950 lb. as the effect of 0.01 per cent phosphorus for basic steel and for acid steel 1050 lb. In his second investigation,§ he gave 1000 lb. for each 0.01 per cent phosphorus for both acid and basic steels.

Doctor Stead states: "In reviewing the work of Stead and d'Amico, that the effect of 0.10 per cent phosphorus is comparable within certain limits with that of carbon."

In mill work, when grading good basic open-hearth steel, there is little need of considering the differences in the effects assigned to the unit of phosphorus, as the phosphorus in this steel does not generally vary more than four points, while the additions to the tensile strength, when estimated by the different methods referred to, varies from about 1500 to 3000 lb. per sq. in. Most of this is generally covered by the differences in the values given to the effects of manganese and carbon. Satisfactory results are obtained in rolling steel under all of these varying methods.

There has always been a great difference in the opinions of investigators and manufacturers of steel regarding the effect of manganese on its tensile strength. Some claim that the effect was slight, others that there was no effect on basic open-hearth steel until the manganese was above 0.40 or 0.60 per cent but most of them admit its effect on acid open-hearth steel. Webster's values for manganese varied, decreasing per unit as its content increased. He found the effect on basic open-hearth steel was less than on basic bessemer steel. In part they were as follows:

	Lb. per Sq. In.
Basic open-hearth steel with 0.35 manganese, 0.01 per cent.....	163
Basic open-hearth steel with 0.55 manganese, 0.01 per cent.....	151
Basic bessemer steel with 0.35 manganese, 0.01 per cent	223
Basic bessemer steel with 0.55 manganese, 0.01 per cent	189

Vosmaer in 1891, in *Mechanical and Other Properties of Iron and Steel*, gives the effect of:
0.01 per cent of carbon as 853 pounds per square inch.
0.01 per cent of phosphorus, one-fourth the effect of carbon, as 213 pounds per square inch.
0.01 per cent of manganese, one-fifth the effect of carbon, as 170 pounds per square inch.

Campbell in his first investigation gave, in basic open-hearth steel, 0.01 per cent manganese a value of 85 lb. He gives in his second investigation¶ complete tables for the effect of manganese in both basic and acid open-hearth steel, showing that its effect per unit increases with the increase of the carbon in the steel.

§Trans. (1905) 35, 772.
¶Trans. (1905) 35, 772.

Cunningham's rule,^o "To find the approximate tensile strength of structural steel to a base of 40,000 lb. add 1000 lb. for every 0.01 per cent carbon, and 1000 lb. for every 0.01 per cent phosphorus, neglecting all other elements in normal steels. Radical variations between calculated and actual strength indicate mixed steels, segregation, incorrect analyses, or unusual treatment in manufacture" was a good guide for basic open-hearth steel, as the base of 40,000 lb. (2812.3 kg. per sq. cm) was high enough to include the effect of the average amount of manganese in structural steel.

Grading of Steel.

During the last seven or eight years, some steel works, from their own data and tension tests of rolled material of different weights and thickness on former orders, have made their own tables for rolling similar materials on new orders. The results are most satisfactory, as the makers have at once the data required to grade and roll heats of steel best suited to comply with the requirements of each order. These tables cover not only the thickness of the steel but all other rolling conditions at the particular mill for which the table is designed. Formerly, it would have been almost impossible to collect such data, owing to the large number of specifications in general use. They were good, bad, and indifferent and covered all sorts of divisions of the steel. Through the work of the steel committee of the American Society for Testing Materials steel specifications were standardized and many of the old specifications scrapped. The other engineering societies cooperated in this work, and the whole range of structural steel is now covered by about six subdivisions, the limits of each covering a range of about 10,000 lb. (703.1 kg. per sq. cm) in tensile strength. Some of these overlap, as for instance, 55,000 to 65,000 lb. per sq. in. overlaps the 50,000 to 60,000 lb. and 60,000 to 70,000 lb. These standard specifications simplified matters very much in every way. The manufacturers have a larger tonnage to make on a given grade of steel than before, and it become easy for them to collect their records of tension tests and compile good reliable working tables. This enabled them to make better and more uniform steel. These tables are generally based on the results of tests made on steel containing not over 0.02 per cent phosphorus; for higher phosphorus, they add 1000 lb. (453.6 kg) for each increase of 0.01 per cent of phosphorus.

Steel works X uses practically the same form of table, based on records of rolling steel of not over 0.04 per cent phosphorus, but in applying heats with higher phosphorus it deducts 0.02 per cent carbon for each increase of 0.01 per cent phosphorus; that is, it is now using practically the values given by the writer in 1892, when he gave phosphorus 1 7/8 times the effect of carbon when it occurred in steels of 0.15 per cent carbon and over. The grading of steel by these tables has for years given satisfactory results and confirms the work done at Pottstown.

About 1913, steel works A took several thousand tests of its 3/4-in. round bars rolled from small test ingots of basic open-hearth steel, and grouped the results under each 0.01 per cent carbon, from 0.10 to 0.75 per cent inclusive, with the manganese from .34 to 0.96 per cent inclusive, advancing by 0.02 per cent Mn. The following note is taken from this table: "When phosphorus is greater than 0.02 per cent the figures should be increased

^oTrans. Amer. Soc. Civil Engrs. (1897) 38, 78.

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at the rate of 1000 lb. for each 0.02 per cent that the phosphorus exceeds 0.01 per cent."

The same course was followed with the $\frac{3}{4}$ -in. round tests from its bessemer steel, the carbon limits are the

same, but the manganese limits run from 0.34 to 1.16 per cent. As these tables are too large to embody here, the parts covering carbons 0.10 to 0.40 per cent and manganese 0.34 to 0.60 per cent are given. The increase in

Table 1—Steel Works A—Basic Open-Hearth Steel

Phosphorus under 0.031 per cent; manganese 0.34 to 0.60 per cent, varying by 0.02 per cent; carbon 0.10 to 0.40 per cent varying by 0.1 per cent. Average of actual tensile strength of $\frac{3}{4}$ -inch round test bars rolled from test ingots.

When phosphorus is greater than 0.02 per cent the figures should be increased at the rate of 1,000 pounds for each 0.01 per cent that the phosphorus exceeds 0.02 per cent.

Per Cent Carbon	Per Cent Manganese													
	0.34	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50	0.52	0.54	0.56	0.58	0.60
	Tensile Strength, Pounds per Square Inch													
0.10	50,145	50,595	50,950	51,300	51,700	52,100	52,440	52,720	53,000	53,400	53,800	54,200	54,600	55,000
0.11	51,410	51,790	52,090	52,390	52,720	53,050	53,340	53,595	53,850	54,245	54,640	55,025	55,390	55,760
0.12	52,675	52,980	53,235	53,480	53,740	54,000	54,245	54,470	54,700	55,090	55,485	55,850	56,185	56,520
0.13	53,945	54,175	54,375	54,570	54,760	54,950	55,145	55,350	55,550	55,940	56,325	56,670	56,975	57,280
0.14	55,210	55,370	55,520	55,660	55,780	55,900	56,050	56,225	56,400	56,785	57,170	57,495	57,770	58,040
0.15	56,475	56,565	56,660	56,750	56,800	56,850	56,950	57,100	57,250	57,630	58,010	58,320	58,560	58,800
0.16	57,040	57,140	57,240	57,340	57,435	57,530	57,675	57,860	58,050	58,445	58,840	59,180	59,455	59,730
0.17	57,605	57,710	57,820	57,930	58,070	58,215	58,400	58,625	58,850	59,260	59,675	60,035	60,350	60,660
0.18	58,170	58,285	58,405	58,520	58,710	58,895	59,120	59,385	59,650	60,080	60,505	60,895	61,240	61,590
0.19	58,735	58,885	58,985	59,110	59,345	59,580	59,845	60,150	60,450	60,895	61,340	61,750	62,135	62,520
0.20	59,300	59,430	59,565	59,700	59,980	60,260	60,570	60,910	61,250	61,710	62,170	62,610	63,030	63,450
0.21	59,775	60,025	60,275	60,510	60,785	61,055	61,365	61,700	62,040	62,470	62,905	63,320	63,720	64,120
0.22	60,245	60,615	60,985	61,320	61,590	61,855	62,155	62,495	62,830	63,235	63,640	64,030	64,410	64,790
0.23	60,720	61,210	61,700	62,130	62,390	62,650	62,950	63,285	63,620	63,995	64,370	64,740	65,100	65,460
0.24	61,190	61,800	62,410	62,940	63,195	63,450	63,740	64,080	64,410	64,760	65,105	65,450	65,790	66,130
0.25	61,665	62,395	63,120	63,750	64,000	64,245	64,535	64,870	65,200	65,520	65,840	66,160	66,480	66,800
0.26	62,285	63,020	63,755	64,410	64,700	64,990	65,310	65,660	66,010	66,335	66,660	66,990	67,325	67,660
0.27	62,905	63,650	64,390	65,070	65,405	65,735	66,085	66,455	66,820	67,150	67,480	67,820	68,170	68,520
0.28	63,530	64,275	65,020	65,730	66,105	66,480	66,860	67,245	67,630	67,970	68,305	68,655	69,020	69,380
0.29	64,150	64,905	65,655	66,390	66,810	67,225	67,635	68,040	68,440	68,785	69,125	69,485	69,865	70,240
0.30	64,770	65,530	66,290	67,050	67,510	67,970	68,410	68,830	69,250	69,600	69,945	70,315	70,710	71,100
0.31	65,800	66,585	67,370	68,155	68,560	68,960	69,370	69,785	70,200	70,570	70,940	71,305	71,670	72,030
0.32	66,835	67,645	68,455	69,260	69,610	69,955	70,330	70,740	71,150	71,545	71,935	72,295	72,630	72,960
0.33	67,865	68,700	69,535	70,370	70,655	70,945	71,295	71,670	72,100	72,515	72,930	73,290	73,590	73,890
0.34	68,900	69,760	70,620	71,475	71,705	71,940	72,255	72,655	73,050	73,490	73,925	74,280	74,550	74,820
0.35	69,930	70,815	71,700	72,580	72,755	72,930	73,215	73,610	74,000	74,460	74,920	75,270	75,510	75,750
0.36	70,665	71,530	72,400	73,265	73,545	73,825	74,170	74,590	75,000	75,455	75,910	76,295	76,610	76,920
0.37	71,400	72,250	73,100	73,950	74,335	74,720	75,130	75,565	76,000	76,450	76,905	77,320	77,710	78,090
0.38	72,130	72,965	73,800	74,630	75,120	75,610	76,085	76,545	77,000	77,450	77,895	78,350	78,805	79,260
0.39	72,865	73,685	74,500	75,315	75,910	76,505	77,045	77,520	78,000	78,445	78,890	79,375	79,900	80,430
0.40	73,600	74,400	75,200	76,000	76,700	77,400	78,000	78,500	79,000	79,440	79,880	80,400	81,000	81,600

Table 2—Steel Works A, Acid Bessemer Steel

Manganese 0.34 to 0.60 per cent, varying by 0.02 per cent; carbon 0.10 to 0.40 per cent, varying by 0.01 per cent. Average of actual tensile strength of $\frac{3}{4}$ -inch round test bars rolled from test ingots.

Per Cent Carbon	Per Cent Manganese													
	0.34	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50	0.52	0.54	0.56	0.58	0.60
	Tensile Strength, Pounds per Square Inch													
0.10	64,440	64,480	64,480	64,500	64,600	64,700	64,800	64,900	65,000	65,120	65,240	65,340	65,420	65,500
0.11	64,665	64,695	64,720	64,750	64,900	65,055	65,190	65,310	65,430	65,585	65,740	65,885	66,020	66,150
0.12	64,890	64,930	64,965	65,000	65,205	65,410	65,580	65,720	65,860	66,050	66,245	66,430	66,615	66,800
0.13	65,120	65,160	65,206	65,250	65,505	65,760	65,970	66,130	66,290	66,520	66,745	66,980	67,215	67,450
0.14	65,345	65,395	65,450	65,500	65,810	66,115	66,360	66,540	66,715	67,150	67,450	67,750	68,070	68,100
0.15	65,570	65,630	65,690	65,750	66,110	66,470	66,750	66,950	67,150	67,450	67,750	68,070	68,410	68,750
0.16	66,155	66,245	66,340	66,430	66,810	67,190	67,500	67,735	67,970	68,345	68,720	69,090	69,445	69,800
0.17	66,740	66,860	66,985	67,110	67,510	67,910	68,245	68,520	68,790	69,240	69,695	70,105	70,480	70,850
0.18	67,320	67,480	67,635	67,790	68,210	68,630	68,995	69,300	69,610	70,140	70,665	71,125	71,510	71,900
0.19	67,905	68,095	68,280	68,470	68,910	69,350	69,740	70,085	70,430	71,035	71,640	72,140	72,545	72,950
0.20	68,490	68,710	68,930	69,150	69,610	70,070	70,490	70,870	71,250	71,930	72,610	73,160	73,580	74,000
0.21	69,755	69,975	70,200	70,420	70,900	71,380	71,795	72,145	72,495	73,080	73,665	74,170	74,585	75,000
0.22	71,020	71,245	71,465	71,690	72,190	72,690	73,100	73,420	73,740	74,230	74,725	75,175	75,590	76,000
0.23	72,285	72,510	72,735	72,960	73,480	74,000	74,405	74,690	74,980	75,380	75,780	76,185	76,590	77,000
0.24	73,550	73,780	74,000	74,230	74,770	75,310	75,710	75,965	76,225	76,530	76,840	77,190	77,595	78,000
0.25	74,815	75,045	75,270	75,500	76,060	76,620	77,015	77,240	77,470	77,680	77,895	78,200	78,600	79,000
0.26	75,810	76,075	76,335	76,600	77,100	77,615	77,990	78,230	78,475	78,730	78,990	79,305	79,580	80,050
0.27	76,810	77,110	77,400	77,700	78,155	78,615	78,970	79,225	79,480	79,785	80,090	80,410	80,755	81,100
0.28	77,810	78,140	78,470	78,800	79,205	79,610	79,945	80,215	80,490	80,835	81,185	81,520	81,835	82,150
0.29	78,805	79,170	79,535	79,900	80,250	80,605	80,925	81,210	81,495	81,890	82,285	82,665	82,910	83,200
0.30	79,800	80,200	80,600	81,000	81,300	81,600	81,900	82,200	82,500	82,940	83,380	83,730	83,990	84,250
0.31	80,610	80,990	81,370	81,750	82,050	82,350	82,660	82,980	83,300	83,695	84,090	84,410	84,655	84,900
0.32	81,420	81,780	82,140	82,500	82,800	83,100	83,420	83,760	84,100	84,450	84,805	85,095	85,320	85,550
0.33	82,230	82,570	82,910	83,250	83,550	83,850	84,180	84,540	84,900	85,210	85,515	85,775	85,990	86,200
0.34	83,040	83,380	83,720	84,060	84,360	84,660	84,960	85,320	85,700	86,065	86,430	86,740	87,000	87,260
0.35	83,850	84,190	84,530	84,870	85,170	85,470	85,770	86,100	86,500	86,770	87,090	87,410	87,730	88,050
0.36	84,660	85,000	85,340	85,680	86,000	86,320	86,640	86,960	87,300	87,620	87,940	88,260	88,580	88,900
0.37	85,470	85,810	86,150	86,490	86,810	87,130	87,450	87,770	88,100	88,420	88,740	89,060	89,380	89,700
0.38	86,280	86,620	86,960	87,300	87,620	87,940	88,260	88,580	88,900	89,220	89,540	89,860	90,180	90,500
0.39	87,090	87,430	87,770	88,110	88,430	88,750	89,070	89,390	89,710	90,030	90,350	90,670	90,990	91,310
0.40	87,900	88,240	88,580	88,920	89,240	89,560	89,880	90,200	90,520	90,840	91,160	91,480	91,800	92,120

the tensile strength for the 30 points of carbon and 26 points of manganese is 31,455 lb. for basic open-hearth steel and 30,860 lb. for acid bessemer steel.

After several attempts to get a workable table of estimated tensile strengths that would agree with the averages of the actual tests of the basic open-hearth steel given in Table 1, the writer found that by starting with the base given in that table for 0.10 per cent carbon and 0.34 per cent manganese, 50,145 lb. per sq. in. (3525.2 kg. per sq. cm) and giving an increase of 830 lb. (58.36 kg) for each 0.01 per cent of carbon and 170 lb. for each 0.01 per cent manganese, that satisfactory results were obtained.

These estimated tensile strengths are given in Table 3 for each increase of 5 points carbon from 0.10 to 0.40 per cent inclusive, and for each increase of 4 points manganese from 0.34 to 0.58 per cent manganese inclusive. For convenience of comparison, the results of the tension tests from Table 1 for the same subdivisions of 5 points of carbon and manganese are given in Table 3, also the differences between the tension tests and estimated tensile strength. The results agree much better than one would expect, and indicate that manganese has a much greater effect than is usually assigned to it.

pare with the results of steel works X and Cunningham, who do not give it any value.

When taking into consideration all the differences in the six methods used to find the required carbons for tensile strengths called for in the four divisions of the low-phosphorus steels and the two divisions of the higher phosphorus steels, the results agree remarkably well. Any of these methods, by slight modifications to suit the rolling conditions of any mill, could soon be used for the grading of the steel.

These tables were prepared not only for discussion but to induce others to give us similar tables covering their methods used in grading and rolling bessemer steel, basic and acid open-hearth steel and electric steel, also duplex and triplex steels. From a comparison of the methods given for all of these, many important facts would be brought out in the discussion. If any manufacturer does not desire to give full publicity to his methods, they will be submitted to a small committee for a comparison with the other tables and methods given for all of these, many important facts would be brought out in the discussion. If any manufacturer does not desire to give full publicity to his methods, they will be submitted to a small committee for a comparison with

Table 3—Comparison of Results of Tensile-Strength Tests and Estimated Values of Basic Open-Hearth Steel.

Base used for estimate tensile strength for Webster's values 50,145 pounds per square inch for 0.10 per cent carbon, and 0.34 per cent manganese. Phosphorus content 0.02 per cent in all cases.

Per Cent Carbon	Results	Per Cent Manganese						
		0.34	0.38	0.42	0.46	0.50	0.54	0.58
		Tensile Strength, Pounds per Square Inch						
0.10	Steel works A.....	50,145	50,950	51,700	52,440	53,000	53,800	54,600
	Estimated	50,145	50,825	51,505	52,185	52,865	53,545	54,225
	Difference		—125	—195	—255	—135	—255	—375
0.15	Steel works A.....	56,475	56,660	56,800	56,950	57,250	58,010	58,560
	Estimated	54,295	54,975	55,655	56,335	57,015	57,695	58,375
	Difference	—2,180	—1,685	—1,145	—615	—235	—315	—185
0.20	Steel works A.....	59,300	59,565	59,980	60,570	61,250	62,170	63,030
	Estimated	58,445	59,125	59,805	60,485	61,165	61,845	62,525
	Difference	—855	—440	—175	—85	—85	—325	—505
0.25	Steel works A.....	61,665	63,120	64,000	64,535	65,200	65,840	66,480
	Estimated	62,595	63,275	63,955	64,635	65,315	65,995	66,675
	Difference	+930	+155	—45	+100	+115	+155	+195
0.30	Steel works A.....	64,770	66,290	67,510	68,410	69,250	69,945	70,710
	Estimated	66,745	67,425	68,105	68,785	69,465	70,145	70,825
	Difference	+1,975	+1,235	—595	+375	+215	+200	+115
0.35	Steel works A.....	69,930	71,700	72,755	73,215	74,000	74,920	75,510
	Estimated	70,895	71,575	72,255	72,935	73,615	75,295	74,975
	Difference	+965	—125	—500	—280	—385	—625	—535
0.40	Steel works A.....	73,600	75,200	76,700	78,000	79,000	79,880	81,000
	Estimated	75,045	75,725	76,405	77,085	77,765	78,445	79,125
	Difference	+1,445	+525	—295	—915	—1,235	+1,435	—1,875

Comparison of Steel Works A Tension Tests With Estimated Strengths.

In order to make a thorough comparison between the methods used by steel works A and X with the estimated tensile strengths by the methods of Campbell, Cunningham, and Webster, six tables have been prepared, each covering a range of 10,000 lb. (703.08 kg.) in specified tensile strength. Tables 4 to 7 are for steels of about 0.02 per cent phosphorus and not over 0.031 per cent. Tables 8 and 9, for steels containing 0.06 per cent phosphorus, are given to bring out clearly the actual increase in tensile strength by the different methods used.

The limits of manganese, 0.34 to 0.56 per cent inclusive, are much wider than would be used in practice, but they are so made to show more clearly the effect of manganese when used by steel works A, Campbell and Webster, and how the tensile strengths arrived at com-

the other tables and methods given and a short report of its views on same. In this connection, no doubt all of the factors that have a bearing on the quality of the finished steel will be considered and discussed. It is suggested that particular attention be given to the direct or indirect effects of the recarburization of the metal, also to the stock used, etc.

Particular attention is called to the following from Mr. A. A. Stevenson's discussion of one of the writer's early papers:* "You state that 'the quality of steel depends (1) on its chemical composition; (2) on the treatment it received in the course of manufacture.' I would go a step further, and say that, in my opinion, as far as open-hearth steel is concerned, the physical results, to a certain extent, depend on manipulation of the bath in the furnace.

*Jnl. Frank. Inst. (January, 1899), 147, 14.

"Concerning the relations between the chemical composition and physical results, I must say I have been somewhat surprised to find how close this relation is. The point in question has been brought out strongly in test work we have recently done on some tires made for a foreign government to a rather difficult specification."

His remarks on the importance of the treatment of steel in the furnace were considerably ahead of the times, but have been fully confirmed since then, and recently

it has been found that variations in the working of the blast furnace at times produce undesirable conditions that carry through all the way to the finished steel. The conditions referred to are no doubt due to oxygen in the steel, and it is to be hoped that we will have a full discussion on this question.

Underlying this whole matter are the changes in the structure of steel produced by the heat treatment and work it receives in rolling. These changes are recognized

Table 4—Carbon Limits* for Basic Open-Hearth Steel 7/16 inch Thick; Desired Rolling Limits About 52,500-58,000 Pounds.
Phosphorus content 0.02 per cent; specified ultimate strength 50,000-60,000 pounds.

	Low Limit			High Limit		
	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch
Steel works A.....	0.12	0.34	52,675	0.15	0.34	56,475
	0.12	0.56	55,850	0.15	0.56	58,320
Campbell	0.12	0.34	52,346	0.15	0.34	55,496
	0.12	0.56	54,210	0.15	0.56	57,360
Webster	0.09	0.34	52,220	0.12	0.34	55,020
	0.09	0.56	55,100	0.12	0.56	57,900
Cunningham	0.10	0.34	52,000	0.16	0.34	58,000
	0.10	0.56	52,000	0.16	0.56	58,000
Steel works X.....	0.11	0.34	52,000	0.16	0.34	58,000
	0.11	0.56	52,000	0.16	0.56	58,000
Estimated tensile strengths by Webster.....	0.12	0.34	51,805	0.15	0.34	54,295
(See Table 3.)	0.12	0.56	55,545	0.15	0.56	58,035

Table 5—Carbon Limits* for Basic Open-Hearth Steel 7/16 inch Thick; Desired Rolling Limits About 62,000-68,000 Pounds.
Phosphorus content 0.02 per cent; specified ultimate strength 60,000-70,000 pounds.

	Low Limit			High Limit		
	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch
Steel works A.....	0.25	0.34	61,665	0.27	0.34	62,905
	0.25	0.56	66,160	0.27	0.56	67,820
Campbell	0.21	0.34	61,796	0.25	0.34	66,002
	0.21	0.56	63,660	0.25	0.56	67,866
Webster	0.20	0.34	62,020	0.24	0.34	65,220
	0.20	0.56	64,900	0.24	0.56	68,100
Cunningham	0.20	0.34	62,000	0.26	0.34	68,000
	0.20	0.56	62,000	0.26	0.56	68,000
Steel works X.....	0.21	0.34	62,000	0.26	0.34	68,000
	0.21	0.56	62,000	0.26	0.56	68,000
Estimated tensile strengths by Webster.....	0.24	0.34	61,765	0.27	0.34	64,255
(See Table 3.)	0.24	0.56	65,505	0.27	0.56	67,995

Table 6—Carbon Limits* for Basic Open-Hearth Steel 7/16 inch Thick; Desired Rolling Limits About 57,000-63,000 Pounds.
Phosphorus content 0.02 per cent; specified ultimate strength 55,000-65,000 pounds.

	Low Limit			High Limit		
	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch
Steel works A.....	0.16	0.34	57,040	0.20	0.34	59,300
	0.16	0.56	59,180	0.20	0.56	62,610
Campbell	0.16	0.34	56,546	0.20	0.34	60,746
	0.16	0.56	58,410	0.20	0.56	62,610
Webster	0.14	0.34	57,020	0.18	0.34	60,420
	0.14	0.56	59,900	0.18	0.56	63,300
Cunningham	0.15	0.34	57,000	0.21	0.34	63,000
	0.15	0.56	57,000	0.21	0.56	63,000
Steel works X.....	0.16	0.34	57,000	0.22	0.34	63,000
	0.16	0.56	57,000	0.22	0.56	63,000
Estimated tensile strengths by Webster.....	0.18	0.34	58,785	0.21	0.34	59,275
(See Table 3.)	0.18	0.56	60,523	0.21	0.56	63,015

*Carbon limits vary with material rolled and conditions of rolling at different mills.

Table 7—Carbon Limits* for Basic Open-Hearth Steel 7/16 inch Thick; Desired Rolling Limits About 67,000-73,000 Pounds.
Phosphorus content 0.02 per cent; specified ultimate strength 65,000-75,000 pounds.

	Low Limit			High Limit		
	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch
Steel works A.....	0.32	0.34	66,835	0.33	0.34	67,865
	0.32	0.56	72,295	0.33	0.56	73,290
Campbell	0.26	0.34	67,046	0.30	0.34	71,246
	0.26	0.56	68,910	0.30	0.56	73,110
Webster	0.26	0.34	66,820	0.30	0.34	70,020
	0.26	0.56	69,700	0.30	0.56	72,900
Cunningham	0.25	0.34	67,000	0.31	0.34	73,000
	0.25	0.56	67,000	0.31	0.56	73,000
Steel works X.....	0.26	0.34	67,000	0.31	0.34	73,000
	0.26	0.56	67,000	0.31	0.56	73,000
Estimated tensile strengths by Webster.....	0.30	0.34	66,745	0.33	0.34	69,235
(See Table 3.)	0.30	0.56	70,485	0.33	0.56	72,975

Table 8—Carbon Limits* for Basic Open-Hearth Steel 7/16 Inch Thick; Desired Rolling Limits About 57,000-63,000 Pounds.
Phosphorus content 0.06 per cent; specified ultimate strength 55,000-65,000 pounds.

	Low Limit			High Limit		
	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch
Steel works A.....	0.12	0.34	56,675	0.15	0.34	60,475
	0.12	0.56	59,850	0.15	0.56	62,320
Campbell	0.12	0.34	56,546	0.16	0.34	60,746
	0.12	0.56	58,416	0.16	0.56	62,610
Webster	0.10	0.34	57,020	0.13	0.34	60,020
	0.10	0.56	59,900	0.13	0.56	62,900
Cunningham	0.11	0.34	57,000	0.17	0.34	63,000
	0.11	0.56	57,000	0.17	0.56	63,000
Steel works X.....	0.10	0.34	57,000	0.16	0.34	63,000
	0.10	0.56	57,000	0.16	0.56	63,000
Estimated tensile strengths by Webster.....	0.13	0.34	56,635	0.16	0.34	59,125
(See Table 3.)	0.13	0.56	60,375	0.16	0.56	62,875

Table 9—Carbon Limits* for Basic Open-Hearth Steel 7/16 Inch Thick; Desired Rolling Limits About 67,000-73,000 Pounds.
Phosphorus content 0.06 per cent; specified ultimate strength 65,000-75,000 pounds.

	Low Limit			High Limit		
	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch	Per Cent Carbon	Per Cent Manganese	Ultimate Strength, Pounds per Square Inch
Steel works A.....	0.27	0.34	66,905	0.28	0.34	67,530
	0.27	0.56	71,820	0.28	0.56	72,655
Campbell	0.22	0.34	67,046	0.26	0.34	71,246
	0.22	0.56	68,910	0.26	0.56	73,110
Webster	0.21	0.34	66,820	0.25	0.34	70,020
	0.21	0.56	69,700	0.25	0.56	72,900
Cunningham	0.21	0.34	67,000	0.27	0.34	73,000
	0.21	0.56	67,000	0.27	0.56	73,000
Steel works X.....	0.20	0.34	67,000	0.25	0.34	73,000
	0.20	0.56	67,000	0.25	0.56	73,000
Estimated tensile strengths by Webster.....	0.25	0.34	66,595	0.28	0.34	69,085
(See Table 3.)	0.25	0.56	70,335	0.28	0.56	72,825

*Carbon limits vary with material rolled and conditions of rolling at different mills.

in the ordinary fractures and in some cases in the polished and etched surfaces without the use of a glass. Low-power hand glasses have been used to advantage, but there is yet a wide and promising field of microscopical research work on low-carbon structural steel.

In 1894, the writer first called attention to this important point and endeavored to show that at times the chemical composition of steel was of less importance than the poor structure due to improper treatment in heating and rolling. His remarks were in part as follows:†

†Jnl. Iron & Steel Inst. (I, 1894), 45, 335.

“When rolling heavy steel plates, trouble is often caused by finishing them at too high a temperature, which gives a material with crystalline fracture, poor reduction of area, and poor bends. In order to guard against this and control the finishing temperature we use very light drafts in rolling, and produce as good results in heavy plates as in the light ones. Too much importance cannot be given to the heat treatment of steel.”

The writer in 1904 in a discussion of Mr. Campbell's paper said:‡

‡Jnl. Iron & Steel Inst. (II, 1904), 66, 65.

"I agree with Mr. Campbell in that it is not necessary to take the microstructure of the steel into consideration from the standpoint of his investigation. Yet anything that will in any way assist in controlling the heat treatment of the steel should be looked into. In the ordinary microscopical work they have not tied up the fractures of a nicked and broken piece of steel, as we know it, with the microstructure of the same steel. This step from the old to the new has long been needed, and I now desire to call attention to a method of slight etching and low magnification with a hand-glass that is very promising. It looks as though by this method we will be able to tie up the fractures of steel of, say, 0.50 carbon and under. These pieces are from the same bar of 0.35 carbon acid open-hearth steel. One piece was overheated and shows the large coarse structure; the other piece was overheated and then annealed; it shows a much finer structure. A test of this kind would be useful in the case of large driving axles, as a small spot could be polished and etched; the glass would show if the steel had been finished at too high a temperature in forging; that is, if it had too large a grain and was in a dangerous condition. This method of investigation is offered at this time as a suggestion in the hopes that others will take it up and improve it."

The first practical use in examining large forgings as suggested above was by Colonel W. P. Barbo during the war, and he has kindly given me the following describing the results of their work:

"During 1917, Mr. Wm. R. Webster, in conversation with me, showed that in his practice, he had recognized a need which we had but recently developed in our field work, in production of high-quality forgings for war purposes. This need was to discover on polished surfaces, the nature and extent, as well as the probable seriousness of solid non-metallic inclusions which had come to light on finished surfaces during manufacture.

"Mr. Webster then contributed to the service of the Government, through me, a small portable microscope, working to approximately 50 diameters (?), and which could easily be dismounted and packed in a grip, carried to any location in the field, and readily set up on a large forging under examination, and proved its great usefulness in determining the seriousness of such inclu-

lem he gave at that time. For several years this problem appeared difficult to the writer, but the advances in metallurgy of steel since 1892 have practically solved it. The tables of averages of the 3/4-in. round tests of Steel Works A more than cover the wide limits for carbons under 0.40 per cent, without taking into account the changes in tensile strength due to thickness of material rolled, and the varying limits of carbon found necessary to secure the same tensile strength in all thickness of material rolled from the same heat of steel. While not used, this greatly simplified the problem. Doctor Howe in "Metallurgy of Steel" states: "While we cannot accurately qualify the effects of carbon, I believe that for ordinary unhardened merchantable steel, the tensile strength is likely to lie between the following pretty wide limits:

Carbon Per Cent	Lower Limit	Upper Limit	Differences by Webster
0.05	50,000	66,000	16,000
0.10	50,000	70,000	20,000
0.15	55,000	75,000	20,000
0.20	60,000	80,000	20,000
0.30	65,000	90,000	25,000
0.40	70,000	100,000	30,000
0.50	75,000	110,000	30,000
0.60	80,000	120,000	40,000
0.80	90,000	150,000	60,000
1.00	90,000	170,000	80,000
1.30	90,000	115,000	25,000

For the consideration of these limits to be expected in the lower carbons from 0.05 to 0.40 per cent carbon inclusive, the upper and lower limits have been subdivided as shown in Table 10, Howe. In Table 10 is given a subdivision of these limits from 0.05 to 0.40 per cent carbon, inclusive. The second column gives the lower limits and the last column gives the upper limits. The third column is one-quarter of the difference of increase between the upper and lower limits; the fourth column is one-half of this increase; and the fifth column three-quarters of the increase. The upper and lower limits for 0.25 per cent carbon and 0.35 per cent carbon have been added to the limits given by Doctor Howe for convenience of investigation; they are merely the limits between the values that he gives for 0.20, 0.30 and 0.40 per cent carbon. At the foot of each column is given the average effect of 0.01 per cent carbon.

Table 10—Effects of Carbon on Tensile Strength, According to Howe.

Per Cent Carbon	Lower Limit, Pounds per Square Inch	One-Quarter Increase, Pounds per Square Inch	One-Half Increase, Pounds per Square Inch	Three-Quarters Increase, Pounds per Square Inch	Upper Limit, Pounds per Square Inch
0.05	50,000	54,000	58,000	62,000	66,000
0.10	50,000	55,000	60,000	65,000	70,000
0.15	55,000	60,000	65,000	70,000	75,000
0.20	60,000	65,000	70,000	75,000	80,000
0.25	62,500	68,000	73,750	79,375	85,000
0.30	65,000	71,250	77,700	83,750	90,000
0.35	67,500	74,375	81,520	88,125	95,000
0.40	70,000	77,500	85,000	92,500	100,000
Effect of 0.01 per cent carbon	666	750	833	917	1,000

sions in a manner which in no way interfered with the future usefulness of the piece.

"Some such apparatus as that which was provided by Mr. Webster, out of his large previous experience, would be of great use if much more extensively applied in practical inspection and works-control operations."

No paper of this kind would be complete without referring to Doctor Howe's views on the effect of carbon on the ultimate strength of steel, given in "Metallurgy of Steel" in 1892, and without trying to solve the prob-

In Table 11 are given the nearest values of steel works A corresponding to the subdivisions of Doctor Howe's values. These values are given with an increase of two points of phosphorus from 0.02 to 0.08 per cent in basic open-hearth steel; the last column is for bessemer steel containing 0.10 per cent phosphorus. As their tables do not give 0.05 per cent carbon, this table starts with 0.10 per cent carbon. The average effects for 0.01 per cent carbon are given at the bottom of each column.

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It is unreasonable to expect that the values of carbon and other elements that apply to the lower steels can be applied equally well to the higher steel, as the difficulties in meeting the requirements of specifications increase as the tensile strength increases. This is due to reductions in rolling and finishing temperature having a greater effect on the higher carbon steels. An exception to this

each subdivision. The results are much closer than was to be expected and is a step toward the solution of the problem given by Doctor Howe in 1892.

Table 12 shows that the average effect of 0.01 per cent carbon from 0.10 to 0.40 per cent increases with the increase of phosphorus and manganese.

Table 11—Effects of Carbon on Tensile Strength, According to Steel Works A

Per Cent Carbon	Tensile Strength, in Pounds per Square Inch, With				
	P 0.02% Mn 0.34%	P 0.04% Mn 0.50%	P 0.06% Mn 0.72%	P 0.08% Mn 0.80%	P 0.10% Mn 0.94%
0.10	50,140	55,000	60,090	63,000	69,540
0.15	56,475	59,250	65,200	68,000	75,080
0.20	59,300	63,250	69,400	72,700	81,820
0.25	61,665	67,200	72,950	77,770	85,600
0.30	64,770	71,250	78,400	82,000	89,960
0.35	69,930	74,580	82,450	86,000	93,460
0.40	73,600	78,000	89,460	93,000	100,160
Effect of 0.01 per cent carbon	782	800	979	1,000	1,054

Table 12—Comparison of Results Obtained by Howe and Steel Works A.

	Per Cent Carbon	Tensile Strength, Pounds per Square Inch With				
		P 0.02% Mn 0.34%	P 0.04% Mn 0.50%	P 0.06% Mn 0.72%	P 0.08% Mn 0.80%	P 0.10% Mn 0.94%
Howe	0.05	50,000	54,000	58,000	62,000	66,000
Steel works A.						
Howe	0.10	50,000	55,000	60,000	65,000	70,000
Steel works A.	0.10	50,140	55,000	60,090	63,000	69,540
Howe	0.15	55,000	60,000	65,000	70,000	75,000
Steel works A.	0.15	56,475	59,250	65,200	68,000	75,080
Howe	0.20	60,000	65,000	70,000	75,000	80,000
Steel works A.	0.20	59,300	63,250	69,400	72,700	81,820
Howe	0.25	62,500	68,000	73,750	79,375	85,000
Steel works A.	0.25	61,665	67,200	72,950	77,700	85,600
Howe	0.30	65,000	71,250	77,700	83,750	90,000
Steel works A.	0.30	64,770	71,250	78,400	82,000	89,960
Howe	0.35	67,500	74,375	81,520	88,125	95,000
Steel works A.	0.35	69,930	76,000	82,450	86,000	93,460
Howe	0.40	70,000	77,500	85,000	92,500	100,000
Steel works A.	0.40	73,600	79,000	89,460	93,000	100,160
Average effect of 0.01 per cent carbon:						
Howe		666	750	833	917	1,000
Steel works A.		782	800	979	1,000	1,054

was shown about twenty years ago by Mr. A. A. Stevenson, then manager of the Standard Steel Works, who had been interested in the writer's work. He rolled successfully several export orders of locomotive tires, subject to both tension and deflection tests, from heats of acid open-hearth steel graded from their chemical composition by Webster's values. He paid great attention to the reductions in rolling and finishing temperatures of these tires, which met perfectly all the tension and deflection tests called for by the specifications on the unannealed tires. This showed that where all the rolling conditions could be controlled the relation between the chemical composition and mechanical properties could be relied on for steels considerably higher in tensile strength and carbon than the usual structural steel.

The results given and the comparisons made in Tables 10, 11 and 12, with other data given, puts the relation between the chemical composition of steel and its physical properties on a much firmer basis than formerly when carbon alone was expected to account for practically all of the differences in the tensile strength of steel.

For convenience of comparison, in Table 12 the two tables are combined, Howe's values being given on the upper lines and Steel Works A on the lower lines in

PURCHASING AGENTS NOMINATE OFFICERS

It is somewhat unusual for the nominating committee of any national organization such as the National Association of Purchasing Agents to name only one slate for re-election and that slate to incorporate, without exception, the entire board as it now stands. Yet this is exactly what happened when the nominating committee of the N. A. P. A. submitted the following report of their deliberations:

For President—W. L. Chandler, Dodge Sales and Engineering Co., Mishawaka, Indiana.

First Vice-President—A. H. Reinhardt, Poole Bros., Chicago, Ill.

Second Vice-President—T. P. Webster, Dominion Textile Co., Montreal, Canada.

Third Vice-President—A. V. Howland, Tileston & Hollingsworth Co., Boston, Mass.

Fourth Vice-President—S. F. Woodbury, Williamette Iron & Steel Works, Portland, Oregon.

Fifth Vice-President—D. E. Ferguson, H. K. Porter Co., Pittsburgh, Pa.

Treasurer, W. J. Gamble, Vulcan Steam Forging Co., Buffalo, N. Y.

Secretary—L. F. Boffey, 19 Park Place, New York, N. Y.

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Boiler Water Treatment Plants

Specifications for Ideal Water Purification Plants — Correcting
Bad Water — Determination of Hardness — Scale and Corrosion.

By ROBERT JUNE, M.E.

HAVE you ever visited a salt plant? If so, you must have watched with interest the processes of evaporation in the salt pans. The brine enters the pans as a clear liquid, but as soon as heat is applied the water begins to disappear in steam, and the salts are deposited. As you watched the deposits of salts increase, did it occur to you that an identical process to that going on before you was constantly going forward in your boilers?

In the case of the boiler, the entering water is not loaded with the same high percentage of salt, to be sure, but the quantity of impurities is higher than is generally appreciated, and when you consider that there are literally many tons of water evaporated in the average boiler every day, and all the various salts and other impurities carried into the boiler remain there until some definite action is taken to effect their removal, the fact becomes apparent that in dealing adequately with the impurities in water, we have a problem of real magnitude.

The importance of boiler water treatment is, indeed, not generally realized, because the size of the operating losses resulting from failure to remove or neutralize impurities in the feed water is not understood. These losses are caused by the formation of scale which reduces boiler efficiency and capacity, and by the pitting and corrosion of boiler tubes, which makes necessary their replacement.

Trouble Resulting From the Use of Bad Water.

In addition to causing scaling and corrosion, bad water causes foaming or priming. These troubles are self-evident. There are other troubles, however, which are due to bad water and which are not so apparent. The good or bad condition of pump valves, and connections and feed lines, is largely dependent upon the quality of the water used, a fact which becomes evident when we suddenly lose the feed to a boiler and perhaps the boiler, or a good part of it. Nor do we always directly connect the breaking of a piston rod, cross head, or cylinder head with excess causticity or precipitates mixed with steam. Other losses which may often be traced to bad water are gradually increased steam consumption, excessive wear on packings and moving engine parts, and increased lubrication.

While these losses may not always be directly traced back to boiler feed, it is a fact that when our

water is constantly purified there is very much less likelihood of these troubles occurring.

Correcting Bad Water.

The neutralization or elimination of impurities in feed water may be effected by one or more of the following methods:

- I. By chemical means.
 - a. Boiler compounds.
 - b. Water softening plants.
- II. By mechanical means.
 - a. Tube cleaners.
 - b. Blow off.
 - c. Filter plants.
- III. By thermal treatment.
 - a. Feed water heaters.
 - b. Distillation plants.

Before discussing these means of removing trouble, let us inquire further into the sources of our difficulties. We find that our troubles and their causes are as follows:

Scaling—caused by the presence of sediment, mud, clay, readily soluble salts, bi-carbonate of magnesia, lime, iron, sulphate of lime, organic matter, etc.

Corrosion—caused by the presence of grease, organic matter, chloride or sulphate of magnesium, sugar, acid, dissolved carbonic and oxygen, and also by electrolytic action.

Priming—caused by the presence of sewage, alkalis and carbonate of soda in large quantities.

F. J. Crolus, steam engineer, of the Carnegie Steel Company, classifies the various inorganic impurities in the manner shown in Table 1.

Table 1.

Free CO ₂ — which is corrosive	{ are negative hardness,
Na HCO ₂ — which is not corrosive	{ but not scaling
Ca H ₂ (CO ₃) ₂	{ are temporary
MgH ₂ (CO ₃) ₂	{ hardness, but
FeH ₂ (CO ₃) ₂	{ non scaling
MgSO ₄	{ non-corrosive, are permanent
CaSO ₄	{ hardness and scale forming
Fe ₂ (SO ₄) ₃	{ All corrosive, are permanent hardness
Al ₂ (SO ₄) ₃	
CuSO ₄	
H ₂ SO ₄	
	{ and scale forming except H ₂ SO ₄

With the addition of chlorine, the combinations given in the table cause most of our troubles. It is evident that the causes of so-called permanent hardness fall entirely within the sulphate range and as a matter of fact most of our efforts must be directed towards the reduction of sulphates.

The principal scale forming offenders, CaSO_4 and MgSO_4 , are non-corrosive, and the simplest procedure is to convert them to NaSO_4 and Ca or Mg carbonates, which are insoluble, by the addition of sodium. The sulphates of iron, aluminum and copper are usually so low that they can be ignored. This is fortunate, as their removal or conversion are not readily accomplished and when necessary usually requires expensive treatment.

Determination of Hardness.

A 100-cc (cubic centimeter) sample of water to be tested is put in a 250-cc bottle and a standard soap solution (this may be obtained from chemical dealers) run in 0.2-cc at a time, the bottle being shaken vigorously after each addition of the soap solution. Finally a lather is produced that will persist for at least five minutes, and then the volume of soap solution used in cc gives the degrees "U. S." hardness. One degree "U. S." hardness is equivalent to 1 grain of calcium carbonate per U. S. gallon (1 part in 58,349).

Professor Gebhardt employs the following factors for specifying the hardness of water in terms of calcium carbonate per U. S. gallon:

Magnesium carbonate	$\times 1.19$	} = hardness as calcium carbonate, grains per U. S. gallon or U. S. deg.
Magnesium sulphate	$\times 0.833$	
Calcium sulphate	$\times 0.735$	
Magnesium chloride	$\times 1.05$	
Calcium chloride	$\times 0.901$	

It is impossible to judge the quality of feed water merely by the grains of solids per gallon since a large amount of soluble salt such as sodium chloride will not be as deleterious as a very small amount of calcium sulphate.

The scale of hardness usually accepted (grains of dissolved salts per U. S. gallon) is as follows: Soft water, 1 to 10; moderately hard water, 10 to 20; very hard water, above 25.

The following is a rough rating according to the number of grains of incrusting solids per United States gallon:

Less than 8 grains.....	very good
12 to 15 grains.....	good
15 to 20 grains.....	fair
20 to 30 grains.....	bad
Over 30 grains.....	very bad

This applies to calcium carbonate, magnesium carbonate, and magnesium chloride. For water containing sulphate of calcium and magnesium, divide the first column by 4 for the same rating.

The limiting factor in deciding whether a water carrying a large amount of soluble salts may be used for boiler feed purposes is the amount of blowing down necessary to keep the degree of concentration within the limits found by experience.

By the use of proper methods we may accomplish the complete removal of permanent hardness, oil, grease and suspended matter, and may neutralize all their acids. The feed water may be so purified as to contain less than $1\frac{1}{2}$ grains per gallon of hardness, due to calcium carbonate and magnesium hydroxide. The total of encrusting substances, including silica, may

be so reduced as to be less than 2 grains per gallon. This is the standard of purification which can usually be obtained and towards which we should work.

Scale.

The character of scale varies from that of a porous, friable crust, to a dense very hard coating. The amount of impurities present in the water cannot be used as a basis for pre-determining the amount of scale which will be formed, as this depends on the type of boiler, rate of driving and the nature of the scale forming ingredients.

In Table 2 we have the results of a number of tests made on locomotive boiler tubes with different thicknesses and character of scale. The variations in conductivity show the futility of basing any calculations on the thickness of scale. Thus test No. 1 shows a decrease of conductivity of 9.1 per cent for a scale of 0.02 inch thick, while No. 16 shows a decrease of only 6.75 per cent for a scale over $6\frac{1}{2}$ times as thick. In each case the scale was even, hard and dense.

Table 2.

INFLUENCE OF SCALE ON HEAT TRANSMISSION*

No.	Thickness of Scale, Inches	Character of Scale	Decrease in Conductivity, Due to Scale Per Cent
1	.02	Hard, dense	9.1
2	.02	Hard	2.02
3	.033	Soft	4.3
4	.033	Very hard	3.5
5	.038	Medium	4.03
6	.04	Soft, porous	6.82
7	.04	Hard, dense	3.07
8	.042	Very soft	9.54
9	.047	Hard	2.75
10	.065	Medium	2.39
11	.07	Soft	2.38
12	.07	Hard	4.43
13	.085	Soft, porous	19.0
14	.089	Very soft	4.95
15	.11	Hard, porous	16.73
16	.13	Hard, dense	6.75

The presence of scale, however, does cause material reduction in the heating surface, and in the volume of water held in the boilers. Thus a 4-inch boiler tube, when clean, has an internal area of 141 square inches per foot of length, but should this tube become lined with $\frac{1}{4}$ inch of scale its area per foot of length is reduced to 122 square inches. We thus find that a quarter inch of scale reduces the actual heating surface by about 11 per cent and the volume of water by about 12 per cent. Furthermore, the reduced area of the tubes tends to retard circulation.

Overheating of boiler tubes is the result of the presence of scale. When the deposit is heavy the tubes in the hottest passes of the boiler may become so hot that the pressure will bulge the metal to such an extent that the bursted tube has the appearance of having been drawn. Overheating, even to a moderate degree, may cause gradual crystallization of the steel so that it eventually becomes brittle and can be broken like ordinary castings. The bursting of tubes is one of the most dangerous factors connected with the operation of water tube boilers and as it can always be traced to the presence of scale or oil on the internal surfaces, it follows that from the standpoint of safety and economy such conditions should not be tolerated.

*Tests made at University of Illinois.

Foaming and Priming.

When foaming occurs it can usually be traced to the presence of one or more of the following impurities: emulsified oil and grease, soluble organic matter, and silt in suspension. It may, however, be due to improper methods of handling the boiler, such as irregularity of load, improper firing and feeding, neglect to make periodic changes of water within the boiler, or to improper design of boiler, wrong arrangement of steam piping, incorrect water spaces or steam liberating area.

It is frequently claimed by operating engineers that the direct cause of priming and foaming in boilers is the presence of sodium salts in the feed water and of the sodium salts, sodium carbonate or soda ash is the one most often charged with causing foaming. The trouble in such cases, however, is not due to the soda ash, but to the wrong application of it. It will usually be found that where foaming occurs with soda ash, that no provision is made of the removal of precipitates formed by its reaction with the scale forming substances in the water. The result is the water becomes so befouled with impurities that priming and foaming occur.

Foaming may also be caused by the introduction of soda ash in an open heater which receives more or less animal oil with the exhaust, and the mixture of this organic oil with water containing sodium carbonate produces a soapy emulsion in addition to lime and magnesium precipitate.

Corrosion.

Corrosion is evidenced by small pits or depressions and by large cup-shaped hollows on the metal surface, and occasionally by a considerable destruction of a large portion of the surface. Carbonic acid gas, occluded oxygen, sodium, calcium and magnesium chlorides are common causes of corrosion. Magnesium and calcium chlorides are very pernicious in that they produce free hydrochloric acid on hydrolysis. Corrosion is also found in boilers using a high percentage of condensate or distilled water.

Where pitting and corrosion occur under deposits of scale, the trouble is usually due either to the presence of free acid in the water or to the liberation of acid by the dissociation of magnesium compounds or other substances.

The corrosive effect of sulphuric acid in the boiler follows an unending cycle of first dissolving iron and then precipitating it, liberating the acid which again immediately dissolves more metal. As a consequence of this condition a small amount of sulphuric acid within the boiler keeps up a constant attack on the metal and this corrosive action may occur with a boiler feed water in which no free acid is present when delivered to the boiler.

Pitting and corrosion, when found in equal intensity both above and below the water line, may be attributed to the presence of hydrochloric acid, which is volatile at boiler temperatures. While hydrochloric acid is not found in feed water it may be formed in the boiler from the decomposition of the chlorides of calcium or magnesium.

Sources of Water Supply.

Boiler feed water is obtained from any one of four principal sources, as follows:

1. Condensate.
2. Bays or lakes of fresh water.
3. Flowing streams.
4. Wells.

There is a fifth source of supply, city water, which, while it originates in one of the four sources listed above, demands separate consideration because of the treatment this water undergoes to fit it for public use.

Condensate. Condensate is certainly the ideal form of feed—a fact nowhere better evidenced than in the design of our modern central stations. Every effort should be made in all plants without exception to see that not a pound of exhaust steam from auxiliaries, pumps, stoker engines, traps, etc., is allowed to go to waste.

Lakes and Bays. Lake water has the merit of uniformity, and when a practical method of purification has once been developed, a standard of practice can be set up and maintained year after year. Lake water is almost invariably alkaline, seldom badly bi-carbonate, and in general presents no serious problem.

Flowing Streams. With rivers we have an individual problem as one stream is acid and the next alkaline. Moreover, the number of parts of impurities to the gallon varies not only from season to season, but daily and hourly. There is one redeeming feature, however, in that this variation in the quantity of impurities does not extend to the ratio of the impurities one with another. This means that in dealing with river water, we can count on the same relative percentages of impurities one with another at all times, and this greatly simplifies our problem.

Wells. Wells are seldom used for boiler feed when other sources are available. Generally speaking they contain a concentration of impurities, and while the water is almost uniform in its analysis, still the quantities of impurities to be disposed of are so great that adequate treatment is a real problem.

City Water. City supply while pure enough for drinking purposes is usually a dangerous proposition for boiler feed. It is very apt to contain chlorine, which presents a serious problem in itself. If it has been filtered, the organic matter has largely been removed, but the scale forming salts remain.

Specifications for Ideal Water Purification Plant.

The ideal water purification plant should measure up to the following specifications:

1. It should produce a water with which can be maintained an internal boiler condition of pre-determined alkalinity, without bi-carbonate, without scale formation, without corrosion and without foaming.
2. There should be no deposits in the feed lines and pumps and no undue wear on valves and moving parts.
3. There should be no bad effects from carried over steam to prime movers, packing or lubrication, or to the product, if steam is used for industrial purposes.
4. It should involve a minimum of expert attention and should require only simple standard mechanical elements, using standard reagents and standard indicators.
5. Filters should not be required.
6. Its capacity should be unlimited and the cost low.

In a later paper we will discuss in detail the individual methods of water purification.

Development of A Powdered Coal Plant

Some Controlling Features in the Use of Powdered Coal—Many of These Have a Direct Bearing on the Economical Operation of the Plant.

By CHARLES LONGENECKER.

THE principal reasons for the substitution of powdered coal for other fuels is the saving in fuel cost and in labor. These savings are, in the majority of cases, realized but in some cases the saving, while very substantial is not as large as expected. This is generally due to the failure to appreciate the significance of features which at first sight are not recognized as vitally important or it may be due to an incorrect valuation of certain of the physical characteristics involved in the success of the undertaking.

Where there are so many variables and where the "human factor" is such a controlling one, it is extremely difficult at times to appraise each factor at its true worth. Some factors appear of greater significance than warranted while others, seemingly trivial, on development, assume an importance never imagined. It is this feature which adds value to experience and by experience alone is it possible to truly balance those controlling features which arise in fuel and furnace engineering, as well as in other classes of engineering. For this reason, as well as others, it is well to look to engineers experienced in the work before undertaking an installation of the kind under discussion.

The features then to be considered, as having a direct bearing on the economical operation of a plant are the following:

1. The grade of coal.
2. Motive power.
3. Equipment.
4. Furnaces in which the coal is burned.
5. The personal factor.
6. The per cent of time the plant is operated.
7. Output of the furnaces.

Fixed charges are not considered as it is only plant operation which is under discussion. These charges, too, are variables for each plant and not of interest as purely engineering topics.

The Grade of Coal.

Before designing a plant it is absolutely necessary to know the analysis and physical characteristics of the coal to be supplied. This is imperative as the quantity of coal handled will depend upon its Btu. content and the manner in which it is prepared on other characteristics. Also guarantees covering the machinery will be based on these features. The coal can vary within certain limits as to moisture, volatile and ash content, but once a certain coal has been used there should be no radical departure from this grade. Thus should a coal of, say 13,000 Btu. content be burned steadily and then without warning a coal of 11,000 Btu. be put in the lines it is most likely that the operation of the system would be greatly disturbed with a consequent disruption of operating routine.

The "moisture content" is certainly a controlling feature especially in the influence it exerts in the preparation of the coal. There is at present much discussion as to whether it is necessary to dry coal before pulverizing it. The answer to this question will depend on the

particular coal being considered. Where all the coal is taken direct from the mine to the coal plant, as is the case where the mine and plant are relatively close to each other, there will be little need for a dryer. This also applies where the moisture content of the coal as received is very low. But where the coal is hauled long distances and is liable to be received in a "water soaked" condition the installation of a dryer is advisable. The characteristics of Eastern and Mid-Western coals are different and where it may not be necessary to dry an Eastern coal it may be absolutely necessary to dry a Western or Mid-Western coal. It is very hard to give specific rules governing this feature as the drying of coals must be in accordance with the characteristics of the particular one to be furnished. Quite a latitude is permissible, in the analysis of the coal, when burned as a powder but the fact is frequently overlooked that a poor grade of coal will not give the results that can be expected from the better grades. There is no way whereby a greater percentage of the heat value of any coal can be released than by burning it pulverized, when burned under the proper conditions. But it must be realized that the original heat content, as expressed in Btus., determines the upper limit and the method of burning, however perfect, cannot raise this limit. Results will be secured in proportion to the coal used, other conditions being equal. Experience has taught that it generally pays to purchase a good quality of coal rather than the inferior grades and a coal which costs, say a dollar a ton more than another grade, may give results which will ultimately assure a saving in heating cost of two or three dollars over that obtained from the cheaper grade. Of course it is possible to reverse this condition if the furnace conditions are not right which would be the case if the cheaper coal is burned more efficiently. Other conditions being equal it will be found, in the majority of cases, that the most economical results are not secured by using the lowest grades of coal.

By powdering coal it is possible to utilize some grades, very low in heat value, which cannot be burned economically otherwise. Thus some lignites and peats are being utilized in this form and the efficiencies obtained are far higher than can be realized where other methods of burning are employed.

The mere act of pulverizing will not create a valuable heating agent out of any inferior grade of coal unless that coal has the inherent heat value. The act of pulverizing changes the physical state only and unfortunately by no form of necromancy is it possible to put heating power into a substance where none originally existed. The change in form does give value—"form value"—so that it is possible to burn the coal with the greatest efficiency.

Anthracite coal, due to the low volatile content, and abrasiveness presents difficulties which are not present in bituminous. There can be no question as to its heat content, where the ash content is average, but so far it has not proved as satisfactory as bituminous coal.

For open hearth furnaces it has been found that the best grade of coal obtainable is the most economical. This coal is one low in ash and sulphur and high in volatile such as the Elkhorn coal of Kentucky or other coals of like analysis.

During the war, when it was extremely hard to get deliveries of particular grades of coal, and at times to get any, the supply to the furnaces was liable to fluctuate from day to day and there was no alternative but to accept conditions with the best grace possible. This necessitated more alertness on the part of the furnace operator but by simple adjustments it was possible for him to get the conditions which he desired as far as output is concerned. The flexibility of a powdered coal system is one of its strong features as it lends itself to rapid adjustments to suit the variations which arise and which cannot always be foreseen.

The "moral" to the foregoing is that the cheapest grades of coal are not always the most economical when the final heating cost is computed.

Motive Power.

Here the desired datum is uniform conditions. A change in voltage will cause a change in motor speeds and this in turn will alter the feed of coal to the furnaces. One instance came to the attention of the writer. Here the power was furnished by a "service" company and for certain reasons the fluctuations were extremely wide and hence it was practically impossible to keep the coal supply to the furnaces steady. It is easy to appreciate the ill effects following such a condition. Fortunately this defect is not frequently met and in most cases there is no need for complaint.

Equipment.

Powdered coal equipment has been very well standardized and knowing the conditions prevailing engineers should have no great trouble selecting the machinery best suited to the conditions to be met. Very frequently where difficulties arise it is due to the failure to correctly analyze and properly visualize the particular conditions pertaining to the plant where the installation is to be made. Whatever the class of fuel, there are very few plants where the requirements are similar in all details and the differences existing must be reckoned with.

In deciding on the requirements of a plant the proper place to start is at the furnaces and work from this to the preparing and distributing equipment. When the amount of coal to be consumed has been determined the capacity of the pulverizing and auxiliary equipment is readily found. Of course it is assumed that the grade of coal to be burned has already been decided upon. In this connection the particular class of metallurgical operation—using the term in a broad sense—to be carried out must be given consideration. The guarantees covering the performance of coal handling machinery are based on the class of coal to be handled—dried, pulverized and distributed—and hence this should be stipulated.

The various pieces of machinery needed for a complete installation have been so well perfected that there is little cause for apprehension as to their operation. The important feature in this regard is to secure the most approved layout and equipment for economical operation. Manufacturers of this machinery are continually looking for improvements and there is always a trend towards the reduction in power required to drive the different pieces of apparatus. Keeping in mind the fact that the

history of powdered coal has been confined to the last eight years, as it relates to industrial furnaces, it will be recognized that the progress in that time has been most commendable.

Furnaces.

Granted that the coal has been properly prepared and delivered to the furnaces the successful burning of it is absolutely essential to assure the success of the undertaking. All too frequently the furnace has been a much understood piece of equipment. It has not been given the standing it should have. Again in some instances a collection of brick, steel and cast iron has had conferred upon it the name "furnace" when it certainly does not merit such an exalted term if heating efficiency is taken as a standard. Due to the fact that it is possible to heat material in a fairly satisfactory manner in most any type of furnace efforts are not made to go beyond this degree of satisfaction but to be content. This does not apply to the burning of powdered coal especially but to furnaces in which other fuels are burned as well. The desire here is not to give a definition to the word "furnace" but to emphasize the bearing it has in carrying out the object in substituting powdered coal, viz: a reduction in the fuel cost.

In some of the earlier installations, it must be said in justice, that experience had been too scanty to disclose many of the errors in furnace construction. Today there is little excuse to offer where errors are committed but naturally there is the desire of always improving on past performances.

Where powdered coal is applied to boilers, hand or stoker fired, there is no question but that the furnace construction must be altered completely. In changing the furnace for this fuel it is made with a greater volume. This alteration, increase in furnace volume, is one which would be beneficial to many installations which are stoker fired, or hand fired, as too often not enough combustion space is provided and the gases have not time enough for complete combustion.

The tendency to economize in building furnaces is, at times, carried too far and for the sake of a small saving in installation cost hundreds of dollars are wasted in fuel. As a general rule in applying powdered coal the combustion space is increased in volume. It invariably follows when such an increase is made and the original fuel is again burned in this enlarged combustion chamber far better results are obtained as compared with the results secured in the old setting. In one case where natural gas had been supplanted the saving in heat secured with powdered coal was equal to one-half of the heating power of the natural gas. Tests showed that the gas was only partly consumed. When powdered coal is not being consumed completely it is most evident to the eye and no instruments are needed to indicate the lack of air. If too much air is supplied then instruments are of service but an experienced operator will be able to burn coal in this form very efficiently due to the results, up to a certain point, being so apparent to the eye.

Stress is to be laid on the point that besides a low priced fuel of high Btu. content, as far as can be obtained, there must be a furnace capable of utilizing the fuel to a high degree of efficiency. Where one fuel supplants another and the furnace is unchanged the saving will be reckoned on the difference in the cost of the fuel, other features being equal. But if besides this saving an additional one is realized by better heating conditions, which means a less Btu. expenditure, a twofold economy is affected.

Due to the low price of coal, oil and gas there has been little incentive to devote much money towards improving the design and operation of existing furnaces but we are approaching a time, if it is not already here, when greater attention must be given to improved furnace construction. Refractories too are not as low as they were and repairs are higher so that the aim must be to reduce this cost per unit of material heated. If more attention is given to this feature of plant maintenance managers will be able to keep the heating cost within reasonable limits compared to that which obtained some years ago.

The question of the "human equation," in connection with furnace operation, is always a difficult one and will probably always so remain. In some instances the breaking of a precedent has aroused some resentment but in the majority of cases when the workman appreciates that the change will work to his benefit there is usually active coöperation. The aim has been to so equip furnaces that the operation with powdered coal

will not differ materially for that in vogue before the change was made.

The percent of time a plant is in operation vitally influences the cost of operation. The greatest saving is made when the whole coal handling plant is operated at maximum capacity and naturally where only part time operation is carried on the savings will be proportionately decreased. This is a factor that cannot be reckoned with as it is controlled by conditions on which there is no method of reckoning.

The output of the furnaces also has a decided influence on the cost sheet as the greater the output the less the cost per unit of material heated. This is another feature which is dependent on business conditions, or orders received, but has no bearing on the way the plant is operated. Here consideration is given only to the time element as influenced by product to be turned out. The operation of the furnace will be diminished, in output, when orders for material heated in the furnace fall off.

New Industrial Oil Burner Creates Interest

**Due to the Shortage of Natural Gas In Many Cities, for Industrial Purposes, Oil Is Used as the Principle Substitute for Heating—
New Burner as Applied to a Forging Furnace.**

THE Anderson-Garner-Shaner oil burning apparatus is an invention which arose as a necessity to meet industrial and domestic heating requirements at times when there are shortages in the natural gas supplies. It is a general practice in Pittsburgh, Cleveland, Buffalo, Wheeling, Cincinnati and Columbus to cut off the industrial consumers of nat-

ered by a small fan or blower, is adequate for all of the heat requirements of any metal, heat-treating, forging, or glass plant.

Fig. 1 is a vertical cross-section drawing of an installation in a forging furnace. Reference to the drawing will disclose the manner of installation of burner and the means of oil and air supply of it.

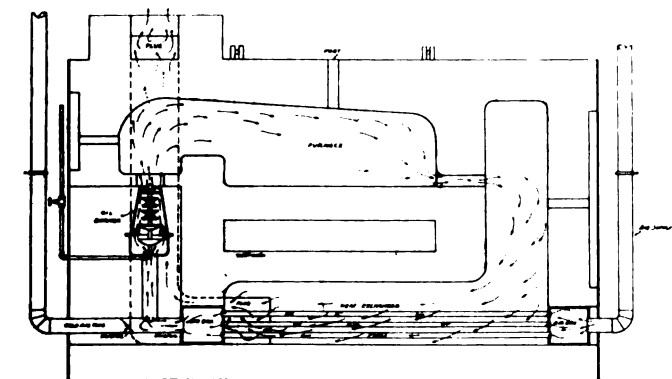


Fig. 1—Cross section of burner as used in forge shop.

ural gas in order that the domestic consumers may have sufficient gas for house heating purposes when the supply is short.

This type of oil burning apparatus is of the gasification variety. It is safer and less expensive to operate than oil burners of either the mechanical or atomizing type. It is as easy to install as a gas burner and as simple in its operation as any gas heating appliance. Oil is consumed without the production of smoke or odorous vapors. Steam, high pressure, air or artificial pressure on oil are not required. Air, under a pressure of from one-half to two ounces, deliv-

The forging furnace is 4 feet wide, 8 inches long, and 5 feet high. Arrangement is made for the exchange of heat between outgoing, hot flue gases and the fresh air incoming, to the burner. All of the heat imparted to the incoming air contributes very materially to efficiency of use of the fuel and makes it possible to attain remarkably high temperatures in the heating chamber.

This forging furnace has been in practically continuous operation for the past three weeks and at no time has the temperature of the flue gases at a point 6 inches above the furnace been in excess of 650 degrees F. Temperatures of from 2,600 to 2,800 degrees F. are readily obtained and maintained in the heating chamber. It is possible by means of thermostatic connections to maintain and control any desired temperature between 500 degrees F. and 2,800 degrees F.

The consumption of oil in heating up the forging furnace varies from 5 to 6 gallons per hour. The time required, depending upon the oil consumption, is from 1 to 1½ hours. When once the temperature of the furnace has been raised to the desired temperature of from 2,000 to 2,800 degrees F., the oil consumption, to maintain this temperature, varies from 2½ to 3 gallons per hour.

The A-G-S oil burning apparatus is manufactured and distributed by the Pittsburgh Saw & Manufacturing Co.

New Books on Roll Pass Design

Prof. Trinks Reviews Two Recent Books On This Interesting Subject — They Stand Out As the Foremost Books Yet Published On Roll Pass Design.

Review by W. TRINKS

THERE are no good books in the English language on the subject of roll pass design; the art is carried on by exchange of information and of experience between members of the trade. Continental engineers have been more liberal with their experience and have published their knowledge for the benefit of others. The books by Geuze, "le laminage du fer et delacier" and by Brovot "Das Kalibreiren der Walzen" are well known in the United States and have been extensively used. However, both of these publications are old.

For that reason two comparatively recent publications on the subject will be of interest to roll pass designers. One of these is by F. Dehez. The name is "Walzenkahlrierungen." It was published late in 1919 by Verlag Stahleisen in Dusseldorf, Germany. It contains 46 pages 12 by 15 inches. The other book "Walzen Kahlbrieren" was written by W. Tafel and was published in 1921 by Ruhfus in Dortmund, Germany. It contains 228 pages 5 by 9 inches and eight folded plates.

Professor Trinks of the Carnegie Institute of Technology will give a course in "Roll Pass Design," at that school this winter. The course begins October 3, 1921, and runs to April 24, 1922. Classes will be held every Monday evening from 7:30 to 10:30. Those who wish to take the course should either pass entrance examinations in Algebra, Physics, Plane Geometry, and English on September 20 and 21, or if they wish to enter with advanced standing, present themselves in the evening of September 28, 29 or 30. Additional information can be obtained from the Institute of Technology.

The two publications are quite different in character and really supplement each other. Dehez's book is a collection of successful designs with but little text, while Tafel's book is an explanation of the underlying phenomena and an attempt to find both a reason for and a solution of each of the problems which confront the roll pass designer. Dehez spent his life in the mill and in the working out of successful roll pass designs. The drawings of the latter need but little comment and should be of assistance to any roll pass designer, regardless of whether he knows German or not. The designs cover rails of various sizes and rails used in different methods of rolling. They cover plain and complex angles finger-bars, rib-rails, moldings for safes, skylights and other purposes, rib-treads, mono-styles, single and double railroad ties. No designs are given for simple sections such as flats, rounds, squares or skelp, because as Dehez states, such designs have been published elsewhere, and because the designs are frequently subordinate to economic conditions and to conditions of mill operations. With most of the designs, tabulations and charts are given which indicate the reduction in the various com-

ponent parts of the sections. It is somewhat strange that no designs of I beams have been given. Mr. Dehez died from a stroke while the book was being printed.

Mr. Tafel's book is very different. It is mostly text, and illustrations are only those which the word indicates, namely, means for illustrating text-matter. As the author states the book is an introduction into the theory and into an understanding of rolling and of roll pass designs. The book does not intend to show solutions of some one else's problems, but will help the reader to correctly solve his own problems. It does not give recipes, but aims to give an insight into the reasoning which is necessary for successful roll pass design.

The book takes up nomenclature, calculation of spreading, forward slippage, gripping, and defects in the stock due to improper roll design. It deals with wear of rolls, overfilling and underfilling, location of the passes in the roll, with side work and with many other features of roll pass design. It deals with error made in the design and with their consequences. It then enters into roll pass design, for flats and skelp, for hand and guide squares, hand rounds and guide rounds, every where giving reasons for each step and numerical examples. It takes up pass design for roughing rolls and enters into roll train resistance. Finally it goes into pass design for structural material and similar shapes, saying very little, however, on the subject of I beams.

Tafel who is professor of steel works design in Bresban knows the practice of rolling. He has rolled, and speaks from experience. Many a reader will not agree with all of Tafel's theoretical explanations, but the latter are well advanced over those of previously published books. Those who can struggle through a German text will be well repaid for the effort made in studying the book. One point, which is practically omitted in all other books, namely the design of guide and of guide boxes is treated by Tafel at quite some length. The book well deserves to be translated into English.

For the benefit of those who may wish to purchase either one of these books it should be mentioned that J. E. Steckert & Co., 151 West Twenty-fifth Street, New York City, carry a stock of almost all important German technical books. On account of the low value of the mark, the books are quite inexpensive.

250 YEARS OF BLAST FURNACE OPERATIONS AT WASSERLALFINGEN

The iron works at Wasseralfingen, in Wurttemberg, which have now been in existence for 250 years were not the first iron works of Wurttemberg, which is not conspicuous among the iron-producing countries. But the name of von Faber du Faur, who was manager of these iron works a century ago, is well known, and his suggestion of utilizing the blast furnace gases for generating heat and power, made Wasseralfingen famous. The ore utilized in these districts is the oolitic iron ore (Bohnerz) of the Suabian Jura. The first Wurttemberg iron works mentioned, in 1365, are those of Konigstronn.

WITH THE EQUIPMENT MANUFACTURERS

IMPROVED CONTACTOR FOR D. C. MOTORS

A new and improved form of contactor, known as the bent frame type, for dc motor control, has just been developed by the General Electric Company. The ampere ratings of the new line include a size range of from 50 to 1,500 amperes, and the line also takes in contactors for both normally closed and normally open operation.

These contactors were especially designed to meet the three principal requirements of electric motor drive, namely, continuity of service, simplicity and durability. Continuity of service implies not only the fact that the contactor will work well for a long period of time, but that the wearing parts shall be so designed and constructed that their replacement is a matter of a few minutes, requiring no interruption of service. How the new contactors meet requirements is best seen from an explanation of their mechanical and electrical characteristics.

In the new line, particular attention has been paid to the construction of the parts directly concerned in breaking the circuit. Under severe service conditions contactors of former construction required frequent renewal of the tips and arc chutes because these parts were rapidly burned by the concentration of the arc at the tips.

In the new contactors, this concentration of the arc is prevented by: first, the use of large pear-shaped pole pieces, which give an increased force and distribution to the blow-out flux; secondly, the arc chute has been increased in size, which increases its radiation, and restricted at the mouth, which forces the arc across the burning surfaces at such a high velocity that it does not burn them at any spot. Furthermore, the tips have been provided with arcing horns which protect both them, and the screws holding them to the contactor.

By these means the life of the tips and chutes has been greatly increased, and the rupturing capacity of the contactor as a unit has been made much greater than that of previous type. As to replacement expense, an actual life test showed that where it used to be necessary to renew contactor tips about once a week, and the chutes about once a month, both the tips and chutes of the new type contactor were in good condition after six weeks' operation.

The armature construction varies slightly with the different sizes. On the 40-ampere size it is a punched steel plate with a right angle piece bent out at the bottom. On the 80 to 600 ampere sizes it is bent steel U-shaped section to which is attached the arm carrying the moving contact, and on the 900 ampere and 1,500 ampere sizes, the section is of cast steel. The armature fits inside the frame, which is also a U-shaped piece of steel plate, the former being hung on a pin which fits in bushings. The armature and bracket pins both have a longer life in these contactors, due to the direction of the forces acting on them. This means that the contactors will operate satisfactorily for a longer period, with resultant reduced maintenance cost. Another improved feature is the operating coil, which slips on over the core, and is held by bronze washer fitting in a slot in one end of the core. The coils are somewhat longer in proportion to their diameter, which increases the radiation factor, increasing the allowable voltage range on which the contactors will operate. As to the shunts, they are flexible material, and are clamped directly to the contacts, a construction which reduces local

heating for two reasons: one, because the number of joints through which the current has to pass are reduced to a minimum, and the other because they make good contact, being soft even on an uneven surface.

The normally closed contactors are similar to the standard normally open ones, with the addition of extra parts, and present the similar appearance. The frame and armature are inverted, and the contacts held closed by springs.

ARC WELDING SUPPLANTS RIVETS FOR STRUCTURAL WORK

That arc welding is continually finding new and important industrial applications is being demonstrated by numerous reports of successful welding. In a recent publication issued by the Westinghouse Electric & Manufacturing Co., entitled "Arc Welding Applications," many interesting and novel uses of arc welding are explained and illustrated.

One of the applications shown is the first structural steel building ever erected without the use of rivets. The electric arc was employed throughout the entire construction to unite the structural steel members. Inasmuch as the entire construction was tested and approved by the New York Bureau of Buildings, the arc welding process for this line of work has passed from the experimental stage to the practical commercial stage. The trusses are designed for a live weight of 40 pounds per square foot, each truss supporting a panel of 800 square feet. They were tested at a load of 120 pounds to the square foot, or a total load of 48 tons on the two trusses.

The main advantages of arc welding, for this work, are the elimination of the necessity for fabricating the steel parts and the saving of time in waiting for the girders to be fabricated. Another decided advantage of the arc welding method over that of rivetting is that it does away with the noise of rivetting and makes it possible to work day and night without causing any disturbance.

This unique example of the use of arc welding has aroused a great deal of interest in the building trades and industrial plants. Although no extended use of this principle has been made as yet, it is quite possible that great development may be made in the near future.

NEW BROWN COLD JUNCTION COMPENSATED PYROMETER

Patented December 28, 1920.

The Brown Instrument Company, Philadelphia, Pa., is placing on the market a new thermo-electric pyrometer, which is automatically compensated in the instrument for changes in cold junction temperatures and which includes means of setting the pointer of the instrument to zero in the usual manner.

This is an improvement on the method of cold junction compensation developed by Darling in England, in 1909, and an improvement on a few subsequent developments for automatic cold junction compensation brought out since that time. These former methods afforded no means of setting the instrument to zero. It is customary on all electrical instruments, including millivoltmeters and pyrometers, to supply a zero adjuster to enable the user to set the instrument to zero, provided the zero has shifted, due to jars in transportation or with continual service. The Brown method is the only one which embodies this most necessary feature.

NEWS OF THE PLANTS

The Seaboard Iron & Steel Company, 905 Lake Drive, Baltimore, Md., has awarded a building contract for the erection of a new plant on South Pica street, near West street. The works will comprise a number of buildings with main one-story structure for general iron and steel operations. It is proposed to commence erection at once, having the plant ready for service at an early date.

The Carnegie Steel Company, Pittsburgh, Pa., a branch of the United States Steel Corporation, has filed plans for the construction of a new two-story building at 1275 Reedsdale street, Pittsburgh, for general iron and steel production. The new works will cost about \$50,000. Construction will be commenced immediately.

The Triangle Steel Products Company, Chicago, Ill., care of T. C. Casse, 163 Washington street, has plans nearing completion for the construction of a new plant at Michigan City, Ind., to comprise a one-story and basement structure, equipped for the manufacture of steel specialties. The plant will be 250 x 500 feet, and is estimated to cost approximately \$75,000, including equipment.

The Kingsbridge Iron Works, Inc., 408 East Ninety-ninth Street, New York, N. Y., has acquired a portion of the former Morris Park race track, near Fowler avenue, as a site for the establishment of a new plant. An existing building on the tract will be remodeled and improved, and additional structures erected. Plans are being drawn and construction will be inaugurated at an early date. A large department of the new works will be devoted to ornamental iron manufacture.

The Riverside Bridge Works, Martins Ferry, Ohio, is planning for the immediate erection of a number of additions to its plant for increased production. The work will include an extension to the main fabricating works, forge shop and other plant structures, and will double, approximately, the present plant output. The work is expected to cost in excess of \$60,000.

The Minnesota Steel Company, Duluth, Minn., a subsidiary of the United States Steel Corporation, has completed the purchase of water front property in the Morgan Park district, totaling about 330 acres of land. The site extends along the Minnesota side of the St. Louis river, between New Duluth and the company's present works. Tentative plans are under way for the construction of a number of additions to the plant, and it is said that a fund of about \$5,000,000 has been set aside for this purpose.

The Columbus Forge & Iron Company, foot of West First avenue, Columbus, Ohio, has taken bids for the erection of an addition to its plant for increased production. The extension will be one-story, 70 x 200 feet, and 110 x 120 feet, and is estimated to cost close to \$90,000, including machinery. It is proposed to commence erection at an early date.

The Lackawanna Steel Company, Buffalo, N. Y., is arranging to market a portion of the pig iron produced at its different blast furnaces, and the output in the future will be proportioned for the company's requirements at its steel mills and the regular merchant iron market. The company in

normal times operates a total of 9 blast furnaces and 24 open-hearth furnaces, with 11 rolling mills at the main works. The plant uses about 2,250,000 tons of ore, 1,500,000 tons of coal and 650,000 tons of limestone per year. The pig iron to be sold will be handled direct through the company's branch offices.

The Builders' Iron & Steel Co., Garvey street, Everett, Mass., has awarded a building contract for the erection of a new one-story plant for general production, estimated to cost about \$80,000. Ground for the works will be broken at once.

The plant of the Standard Process Steel Company, North Broad street, Phillipsburg, N. J., has been sold by the liquidating committee of the company to W. P. Barba, Thirteenth and Cherry streets, Philadelphia, Pa., and associates, for a consideration said to be about \$50,000, with mortgage of \$10,000. Mr. Barba was formerly a vice president of the Midvale Steel Corporation. The interests acquiring the plant will make a number of improvements in the works and install new machinery, as required, for the manufacture of steel products. It is proposed to inaugurate work at once and have the plant ready for service at an early date.

The Tomahawk Steel & Iron Works, Tomahawk, Wis., is completing plans for the construction of a new plant to replace its works recently destroyed by fire. The new building will be two and three-story, 100 x 180 feet, and estimated to cost about \$80,000. W. P. Ireland is supervising engineer for the work. William Bauman is general manager.

The Hancock Steel Company, Martinsburg, W. Va., has preliminary plans under way for the erection of its proposed new plant at Brocius, W. Va., near Hancock, Md. The works will comprise a main one-story mill, 130 x 200 feet, with a number of smaller buildings, and are estimated to cost in excess of \$500,000, including machinery. Ernest McGeorge, 1900 Euclid avenue, Cleveland, Ohio, is architect. F. Vernon Aken is head of the company, which was organized several months ago.

The Illinois Steel Company, South Chicago, Ill., is completing plans for the erection of a new three-story building at its plant, 92 x 375 feet, estimated to cost about \$350,000. L. C. Holmboe, 3426 East Eighty-ninth street, South Chicago, is architect and engineer.

The Sharon Steel Hoop Company, Sharon, Pa., has resumed production at four of the finishing mills at its plant, following a shutdown of several months. The works will give employment to about 500 operatives. It is planned to place other departments of the works in service at an early date.

The Wheeling Corrugating Company, 2547 Arthington street, Chicago, Ill., manufacturer of steel products, has completed plans for the erection of an addition to its local plant for increased production. The extension will be one-story, 80 x 125 feet, located on Arthington street, and estimated to cost about \$40,000. Paul Gerhardt, 64 West Randolph street, Chicago, is architect.



E. W. Crellin, president of the Pittsburgh-Des Moines Company, has retired. W. H. Jackson has been elected president, O. E. Guibert and W. W. Hendrix, vice presidents, and George A. Smith, secretary and treasurer. Mr. Smith has removed from Des Moines to Pittsburgh and A. C. Pearsall has been made general manager of the Des Moines branch.

✓ ✓

Robert Wilson recently resigned as superintendent of the Fabricated Steel Products Company, Leetonia, Ohio, and is now connected with the Adams Manufacturing Company, East Palestine, Ohio.

✓ ✓

Lawrence Johnson, who for 19 years was factory engineer of the Collins Company, Collinsville, Conn., maker of edge tools, and now associated with Perin and Marshall, will leave for India next month, where he will assume the position of works manager at the Jamshedpur plant of the Agricultural Implements Company, Ltd., Bombay.

✓ ✓

Fred C. Harris, Duluth, general superintendent of the Zenith Furnace Company for the past 17 years, recently retired and has been succeeded by H. A. Brady, who has been assistant general superintendent. His first experience in making iron was at a forge in Schroon, Essex County, N. Y., when he was 14 years old. Then he spent 10 years at the Crown Point magnetite iron mines in New York, where he also gained a knowledge of smelting and in making ferro-manganese. At 35 Mr. Harris was employed at Edith furnace of the American Steel & Wire Co., then he went to Cleveland as general foreman of the Central Furnace Company. For the past 17 years he was general superintendent at Duluth.

✓ ✓

Thomas Chalmers, superintendent of the Tennessee Coal, Iron & Railroad Co.'s by-product plant, at Fairfield, Ala., who went to Colorado for his health several weeks ago, is reported to be much improved and expects shortly to return to Birmingham to again take up his duties. Mr. Chalmers directed the construction of the new battery of ovens at Fairfield.

✓ ✓

Isaac Harter, assistant to the president, Babcock & Wilcox Co., New York, manufacturers of boilers and stokers, was recently appointed general superintendent of the company.

B. D. Lockwood recently resigned as chief engineer of the Pressed Steel Car Company, Pittsburgh, and J. F. Streib, formerly assistant chief engineer, succeeds him.

✓ ✓

George D. McDougall, general superintendent of the Nova Scotia Steel & Coal Co., New Glasgow, N. S., has been appointed chief engineer of the British Empire Steel Corporation, and Archie McColl, secretary of the Nova Scotia company and assistant to the president for many years, will be general manager of the Nova Scotia Steel & Coal Co.

✓ ✓

C. L. Close, manager of the Safety, Sanitation and Welfare Bureau of the United States Steel Corporation, 71 Broadway, N. Y., and G. K. Leet, secretary to Chairman E. H. Gary, left recently for a fishing trip in Northern Canada.

✓ ✓

Charles J. Hunter, vice president and treasurer of the Wheeling Steel & Iron Co., Wheeling, W. Va., has been elected president of the company, succeeding John Duncan, who resigned recently, to become actively associated with the Illinois Company, St. Louis, owner of coal, coke, iron and railroad properties in Southern Illinois. Mr. Hunter, who is now 50 years of age, has been associated with the Wheeling Steel & Iron Co. since he was 19 years of age. Upon graduation from high school he entered the service of the Benwood Iron Works. Alonzo Loring at that time was president of the company. Mr. Hunter continued with the company following the merger of the Benwood Iron Works, Wheeling Iron & Nail Co. and Belmont Nail Co. in 1892. He advanced from the position of office boy to that of invoice clerk, then to paymaster, bookkeeper and purchasing agent, which position he held for a period of 13 years. He then became secretary and treasurer, and finally vice president. Mr. Hunter is the fourth president of the Wheeling Steel & Iron Co. C. R. Hubbard was its first president, and upon his resignation I. M. Scott was chosen to fill the vacancy. A year ago following the merger of the Wheeling Steel & Iron Co., Whitaker-Glessner Company and the La Belle Iron Company as the Wheeling Steel Corporation, Mr. Scott was elected president of the corporation, and Mr. Duncan succeeded him as president of the Wheeling Steel & Iron Co.



Charles V. McIntire recently resigned his position as chief engineer of the International Coal Products Corporation, to become associated with A. Stephen Knowles, 66 Broadway, New York. Mr. McIntire, prior to his connection with the International Coal Products Company, was for five years actively engaged in the design and construction of by-product coke ovens. He served with the Koppers Company for six years as electrical engineer and later assistant chief engineer, and for a period of five years was chief engineer of the Wilputte Coke Oven Corporation, New York.

V V

Homer A. Pardee, general manager of the Halcomb plant of the Crucible Steel Company of America, Syracuse, N. Y., has been appointed manager of the Park works of the company at Pittsburgh, succeeding George I. Page, who resigned recently. James A. Scott, assistant manager of the Park works, has also resigned.

V V

Norman W. Warren was appointed general manager of the Dominion Bridge Company recently, with headquarters at Montreal. He was born at Kensington, Conn., and studied engineering at Yale. In 1911 he became assistant chief draftsman for the National Bridge Company and was appointed the following year chief draftsman. After the National Bridge was absorbed by the Dominion Bridge Company, Mr. Warren was appointed acting manager for Western Canada, and in 1916 became Western manager, which position he has held since that time. He has been chairman of the Prairie provinces branch of the Canadian Manufacturers' Association.

V V

John Duncan, who recently resigned as president of the Wheeling Steel & Iron Co., Wheeling, W. Va., to engage in the operation of coal, coke, iron ore and railroad properties in Illinois, also resigned as vice president of the Wheeling Steel Products Company, Wheeling, the selling organization of the Wheeling Steel Corporation and its subsidiaries, the Wheeling Steel & Iron Co., La Belle Iron Works, Steubenville, O., and the Whitaker-Glessner Company, Portsmouth, Ohio.

Dr. Richard Moldenke was last week a guest at luncheon of the Worcester, Mass., members of the New England Foundrymen's Association, at the rooms of the Worcester Metal Trades Association, that city. H. P. Blumenauer, general manager Arcade Malleable Iron Company, presided. Dr. Moldenke spoke on foundry costs and on his observations of conditions in Europe, gathered during a trip from which he recently returned.

V V

J. T. Kane, who for many years was general superintendent in charge of shipping at the Trumbull Steel Company, Warren, O., now is warehouse superintendent for the Sheet Metal Manufacturing Company, Youngstown, O.

V V

J. W. Hocking, secretary Wheeling Steel Corporation, Wheeling, W. Va., who resigned recently, was secretary of the Whitaker-Glessner Company prior to the combination of that company with the Wheeling Steel & Iron Co. and LaBelle Iron Works, into the Wheeling Steel Corporation.

V V

William C. Reilly, general superintendent of the Youngstown Sheet & Tube Co., Youngstown, Ohio, has been selected by the provincial Government of Nova Scotia as its representative in arbitration proceedings with the Dominion Steel Company, involving settlement for steel used during the war aggregating \$9,000,000. During the war, the Dominion Steel Company erected a large plate mill at the request of the government and entered into a contract for plates for military purposes. When the armistice was signed the contract was half completed, and the government, having no further use for the plates, cancelled its contract. In the interim efforts have been made between the company and the Government of Nova Scotia to agree upon an amicable settlement, but without avail. Mr. Reilly has gone to Sydney, N. S., where the plate mill is located, to meet with representatives of the company.

V V

Allen G. Goldsmith, Milwaukee, who, during the period of 1911-1917 was associated with the American Rolling Mill Company, Middletown, Ohio, in various capacities up to department manager, has been appointed to take charge of the Western European division of the Bureau of Foreign and Domestic Commerce.

Some Pointers on By-Product Coke Oven Operations

STEEL CORPORATION TO BUILD COKE OVENS

It is reported that the United States Steel Corporation are contemplating the building of a large number of by-product coke ovens at New Castle, Pa., the ovens to be used in connection with their various plants located in this vicinity.

It is the intention of that company to build a thirty-mile railroad, connecting up the new by-product plant with the main line of the Bessemer and Lake Erie Railroad at Kaylor, Pa. The survey for the railroad has been completed.

TO STUDY BY-PRODUCT COKE OVENS OF THE SOUTH

G. St. J. Perrott, associate physical chemist of the United States Bureau of Mines Experiment Station, Pittsburgh, Pa., is to be sent to Birmingham, Ala., to study the physical properties of coke in relation to its production and use in the blast furnace. Blast-furnace operators declare that there is a decided lack of knowledge regarding the physical and chemical properties of coke in producing iron ore. In the stress of wartime they found it necessary to use almost anything in the way of coke material that was offered, and, it is said, they found they could use materials that before seemed impossible. It is believed, therefore, that the investigation proposed offers a very fertile field for the obtaining of very interesting information. Conditions are very favorable for the conducting of these investigations at the Tuscaloosa Experiment Station of the Bureau of Mines, where there are quite a number of small blast furnace plants and by-product plants, many of which are ready to carry on investigating work.

STEEL MAKERS AS COKE SELLERS

Not only are the steel companies making the market in pig iron, but they threaten to become the dominating influence in the coke market, at least temporarily. This possibility is suggested by the fact that a Youngstown district steel company, which recently blew in a blast furnace, contracted for its fuel requirements from a nearby steel company having by-product ovens. This company formerly bought beehive coke for its furnaces, as it probably would be doing now if business were normal and the steel companies having by-product plants were using all the coke they produce. The lowest price quoted by the Connellsville operators against the inquiry, which was for about 12,000 tons a month over the remainder of the year, was \$3 per net ton at ovens. The buyer was able to get by-product coke at \$2.50 per net ton, Connellsville base, a saving of 50 cents per ton, or \$6,000 per month. It is necessary to keep by-product plants in partial operation at all times to prevent heavy repair charges, and there are also in some cases gas contracts, and the steel companies in the Youngstown district, and probably in all other districts, which have by-product plants, are producing more coke than they need, since they have only one blast furnace in five on an average making iron.

It was the marketing of surplus pig iron by the steel companies that established market prices in steel-making grades of iron, and now that the steel companies have surplus by-product coke for sale and the capacity for commercial production, the beehive coke producers have a condition to meet that may have to be reckoned with for a considerable time. The fact that many merchant blast furnaces stopped making

iron did not prevent prices from slipping, and likewise the curtailment of beehive coke making has its limitations as a price corrective, seeing that the steel companies must keep their by-product plants going and will take low prices for coke to prevent burdensome accumulations.—Iron Age.

BY-PRODUCT COKE OVEN COMPANY FORMED

The Belgian-American Coke Ovens Corporation, New York, has been formed with a capital of \$10,000,000 to construct and install Piette by-product coke ovens and carbonization equipment for fuel saving. Olivier Piette, of Belgium, holds the patent rights to the coke ovens and appliances, and will be on the board of directors of the new organization, which is headed by Thomas F. Ryan and F. S. Landstreet, both of New York. The latter has been elected president of the company and offices have been established at 25 Broad street. The American corporation will have the assistance of technical experts from Belgium. The European organization is known as the Franco-Belgian Coke Ovens Corporation.

AGREE TO CUT FREIGHT RATES ON STEEL AND IRON

The transcontinental rail carriers have agreed on reduced rates for iron and steel products originating at eastern points, and only need the concurrence of the New England lines to make the reductions effective, G. W. Luce, general freight agent of the Southern Pacific Company, announced.

It is proposed to make the reductions effective October 3. An endeavor will be made to have the Interstate Commerce Commission suspend its long and short haul ruling which prevents the lines from making long haul rate concessions.

MEETING OF THE A. I. M. E. AT WILKES-BARRE

The Wilkes-Barre meeting of the American Institute of Mining and Metallurgical Engineers should prove a very interesting affair to all who attend. The final program has not yet been announced, but among the papers to be presented are the following:

- "Petroliiferous Rocks in the Serra da Baliza." By E. P. de Oliveira.
- "Underground Mine Development, Its Definition and Valuation." By J. B. Dilworth.
- "Geology of the Namma Coal Field, Burma." By Edel Moldenke.
- "Anthracite: A New Domestic and Metallurgical Fuel." By Donald Markle.
- "Mine Fires Extinguished by Sealing." By Douglas Bunting.
- "Ashley Planes for Handling Freight Traffic." By C. H. Stein.
- "General Geology of Catorce Mining District, Mexico." By C. L. Baker.
- "Mechanical Mining of Anthracite Coal." By H. D. Kynor.
- "Power Installation at Coverdale Mine, Pittsburgh Terminal R. R." By Charles M. Means.
- "Automatic Sub-stations as Applied to Coal Mining." By R. J. Wensley.
- "Determination of Electrical Equipment for a Mine Hoist." By Graham Bright.
- "Slush Problem in Anthracite Preparation." By John Griffen.
- "Lynch Plant of the United States Coal & Coke Co." By H. N. Eavenson.

TRADE NOTES

The W. A. Jones Foundry & Machine Co. announce the appointment of Mr. Robt. B. Moir as manager of their New York branch. He will assume his new duties immediately, making headquarters at the present sales office and transmission warehouse of this company, 20 Murray street. He has been actively connected with the home office and factory for a number of years and is exceptionally well qualified to assist in power transmission and general engineering problems. This change will enable the Jones Company to cooperate with their many friends in the New York district even better than in the past.

Mr. E. S. Crosby, sales and advertising manager for the United States and Cuban Allied Works Engineering Corporation has resigned to become manager of the Eastern District of the Celite Products Company, producers of the well known Sil-O-Cel insulating material, and Filter-Cel the ideal filtering medium. Previous to his service in France with the army, he was assistant sales manager for the De Laval Steam Turbine Company of Trenton, N. J. He will make his headquarters at 11 Broadway, New York.

The agency arrangement for the sale of sheet steel heretofore existing between Thos. Firth & Sons, Ltd. of Sheffield and Wheelock Lovejoy & Co. of New York and Cambridge, has been terminated, and Thos. Firth & Sons have appointed as their general sales manager for the United States, Mr. Horace G. Hides of Hartford, Conn., who has for the past twenty years represented Wm. Jessop & Sons.

The stock of Firth Sheffield Sheets will be carried in the warehouse of the Firth-Sterling Steel Company, 312 Hudson Street, New York City, an associate company.

The Lumen Bearing Company of Buffalo, N. Y., and Youngstown, Ohio, manufacturers of the well-known line of machine bronze, brass and bronze, castings and bearings, solders and babbits, have, owing to the increase in their activities, found it necessary to locate in Chicago a branch office that will supply and handle all business of the company west of and including Michigan with the exception of the city of Detroit, and west of a line from Toledo, to Columbus to Cincinnati; Kentucky, Tennessee and Georgia. Mr. H. S. Huncke is the western sales manager, with Mr. Henry Waters as associate salesman. The office is located at 15 North Jefferson street, Chicago.

Advices have been received to the effect the Cincinnati office of the Cutler-Hammer Mfg. Co., Milwaukee, has been moved from the Dwyne building to the Dixie Terminal building. A. R. Maujer, formerly of the sales engineering force of the Pittsburgh office, is now in charge in the Cincinnati district.

Discontinuance of its Boston office recently was announced by the Eastern Steel

Company, but it is understood Harry O. Russ will continue to represent the company in the New England district with headquarters in the New York office, 50 East Forty-second street.

Advices have been received to the effect that the general offices of the La Belle Iron Works are now located in the Wheeling Steel Corporation building, Wheeling, W. Va., possession of the new quarters having taken effect August 15.

A merger has been effected between the Stowell Company, South Milwaukee, and the Pelton Steel Company, Milwaukee, whereby the Stowell Company secures the business of the Pelton Company. It is the intention to continue operating the Pelton plant under the old name and to maintain the same organization. The Stowell Company has had steel casting facilities for some time, but now counts on added capacity and scope of quality.

TRADE PUBLICATIONS

Simon-Carves, Ltd., Manchester, England, have issued a very well illustrated pamphlet covering a coal washing, handling and crushing plant.

"Superheated Steam in Small Locomotives," is the title of a most interesting booklet issued by The Superheater Company. It covers this subject completely.

The new line of electric furnaces which has recently been added to the products of the Westinghouse Electric & Mfg. Co., is very ably described and illustrated in catalog, 9-C, which is being distributed. This type of furnace includes the multiple unit designed for use with heats of 1800 to 2000 degrees F. The small Hevi-duty furnaces of the multiple crucible type may be operated continuously at 2000 degrees F. Hevi-duty industrial furnaces with applications for annealing, hardening, drawing and enameling, are described in minute detail in this publication. A discussion of the characteristics of these furnaces is also given.

Application of Oil Circuit Breakers is the title of a new publication issued by the Westinghouse Electric & Mfg. Co., East Pittsburgh, known as Special Publication 1643. This includes a complete discussion of the application of circuit breakers, together with an outline of the characteristics of several types of Westinghouse oil circuit breakers.

The Wayne Oil Tank & Pump Co., of Ft. Wayne, Ind., have recently issued a series of bulletins on the various problems of burning fuel oil and the necessary equipment therefor. Great pains have apparently been taken not only to describe and illustrate the equipment manufactured by this company, but to give a great deal of information applicable to the general problem of burning oil, and the bulletins should prove of exceptional interest to engineers and plant owners who contemplate using oil as fuel. The bulletins are bound in an

artistic leatherette cover, size 8½ x 10½, which is both handsome and serviceable.

A new catalog, No. S21, issued by the Direct Separator Company, Inc., Syracuse, N. Y., is just off the press. As an introduction to descriptions and illustrations of the apparatus manufactured by this company, a short historical sketch is given, followed by a presentation of the problems "Water in Steam," and "Separating Water from Steam." In addition to descriptions and illustrations of the various types of separators, the catalog contains tables of dimensions for both oil and steam separators, and reports of tests proving their efficiency. Size 6 x 9.

The Atlas Valve Company of Newark, N. J., have recently issued their bulletins Nos. 1, 1-A, 2, 4 and 5 bound in a loose leaf folder, size 6 x 9. These bulletins consider, respectively, the reducing valves, Ideal pump governors, Atlas pump governors and float valves, bronze unions and swing joint pipe fittings, and Victor damper regulators manufactured by the company. The bulletins contain completely illustrated descriptions of the equipment together with price lists.

COMING MEETINGS

September 6-10—American Chemical Society, the Society of Chemical Industry and the American section of the latter organization will hold a joint meeting in New York. Charles L. Parsons, P. O. Box 1505, Washington, is secretary of the first mentioned society.

September 12 — National Exposition of Chemical Industries, in the Eighth Coast Artillery armory, New York.

September 12-17—American Institute of Mining and Metallurgical Engineers, will hold its fall meeting at Wilkes-Barre, Pa. Frederick F. Sharpless, 29 West Thirty-ninth street, New York, is secretary.

September 19-24—American Society for Steel Treating. Annual convention and exhibition at the Manufacturers building, state fair grounds, Indianapolis. W. H. Eisenman, 4600 Prospect avenue, Cleveland, is secretary.

September 29-October 1—American Electrochemical society, fall meeting, Lake Placid, N. Y. Joseph W. Richards, Lehigh university, S. Bethlehem, Pa., is secretary.

October -7—Society of Industrial Engineers will hold fall meeting at Springfield, Mass.

October 10-13 — National Association of Purchasing Agents will hold its annual convention at the Claypool hotel, Indianapolis. L. F. Boffey, 19 Park place, New York, is secretary.

October 17-22 — American Mining Congress, will hold its twenty-fourth annual convention in the Coliseum, Chicago. Also national exposition of mines and mining equipment.

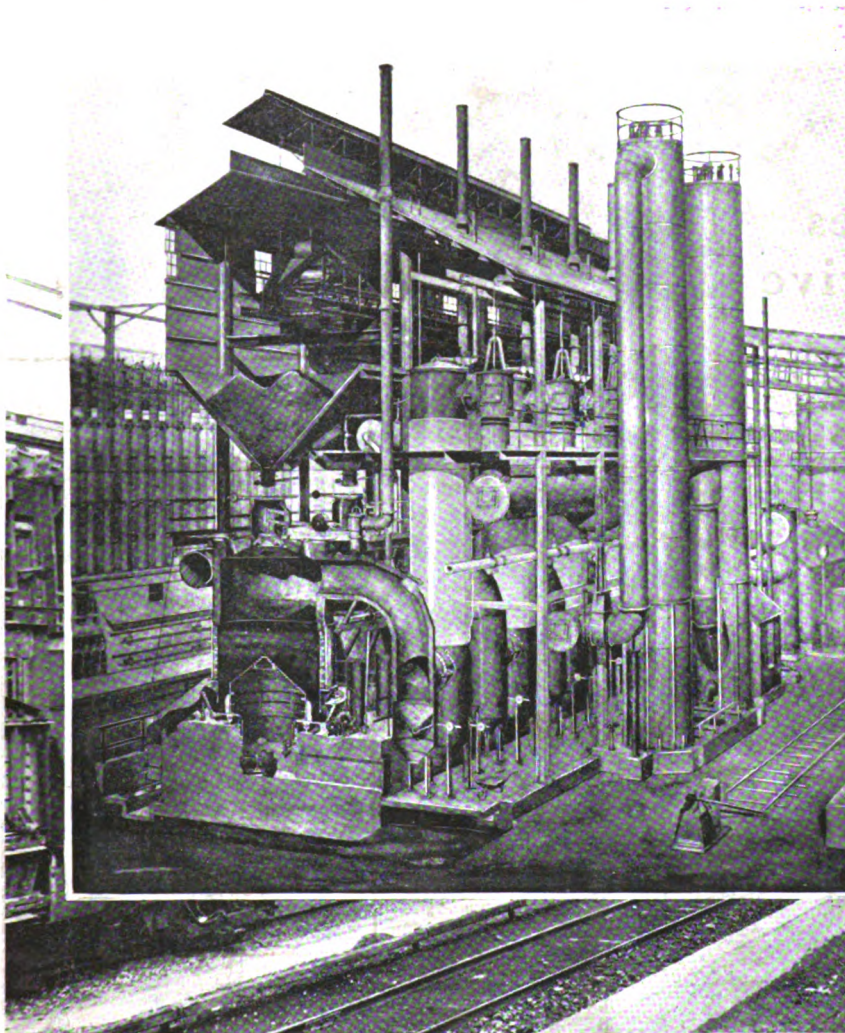
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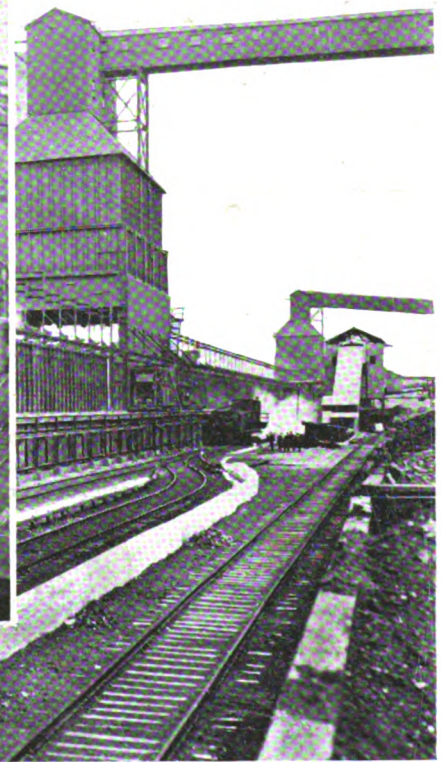
The Blast Furnace *and* Steel Plant

Pittsburgh, September, 1921.

FOR THE STEEL PLANT



**Koppers Combination
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